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SMART GRID STANDARDISATION: CONTRIBUTIONS AND OPPORTUNITIES OF EU HORIZON 2020 PROJECTS

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Standards are critically important for smartening the grid because they affect the interoperability, compatibility, efficiency, and realisation of new technologies and services. In this paper we assess the contribution of EU funded Horizon 2020 projects to adapting or initiating new Smart Grid standards. We provide a comprehensive overview of the Smart Grid standardisation ecosystem and identify opportunities for researchers and innovators to participate in standardisation activities. We identify 225 Horizon 2020 Smart Grid projects and explore which have contributed to the creation or revision of Smart Grid standards. We identify the type of standardisation activities undertaken and explore the factors that influence engagement. We have found that 21 % of EU Horizon 2020 Smart Grid projects engage in some level of standardisation activities. Of these projects the majority (60 %) are involved in understanding standards, 31 % actively engage in influencing standards, while 8 % successfully participate in elaborating new standards. Our study demonstrates that despite the complexity of the Smart Grid Standardisation ecosystem, EU funded researchers and innovators play an important role in the standardisation process.

Keywords: *CENELEC, European projects, H2020, IEC, Research & Innovation, Smart Grids, standards, standardisation, standardisation ecosystem.*

1. INTRODUCTION

Climate change and the need for urgent decarbonisation of power systems in Europe and other countries around the world motivate efforts to transform energy grids into Smart Grids (SG). This transformation process must address multiple challenges, e.g., increasing electricity demand from the electrification of heat and transport, energy price escalation, electricity reliability concerns, and the wide deployment of intermittent distributed renewable energy resources (RES). The development and deployment of Smart Grids around the world is at different stages. However, many countries face a common problem – the lack of standardisation – as seen in [1] and [2].

There has been an increased recognition that more attention needs to be paid to standardisation issues. The importance of standards is emphasised by the recent Pan-European political ambitions stated in the European Green Deal [3] aiming to achieve climate neutrality by 2050 and the preceding "Clean Energy for all Europeans Package" (CEP) which pursues the goals of improving energy efficiency and locating citizens at the centre of the energy transition process [4]. In addition, sector integration [5] strategy emphasises the important directions in the green energy transition, including standardisation and market uptake of sustainable technologies and solutions across different industry sectors. In this light, interoperability becomes a necessary capability of networks and devices so that they can communicate, make sense of information, and react accordingly [6], [7]. In addition, standards developers face a challenge to be technology neutral and find a balance between setting requirements for specific technologies and keeping consistency in requirements across technologies [8].

The revised TEN-E Regulation [9] defines a Smart Grid as "an electricity network, including on islands that are not interconnected or not sufficiently connected to the trans-European energy networks, that enables cost-efficient integration and active control of the behaviour and actions of all users connected to it, including generators, consumers and prosumers, in order to ensure an economically efficient and sustainable power system with low losses and a high level of integration of renewable sources, of security of supply and of safety, and in which the grid operator can digitally monitor the actions of the users connected to it, and information and communication technologies for communicating with related grid operators, generators, energy storage facilities, and consumers or prosumers, with a view to transmitting and distributing electricity in a sustainable, cost-efficient and secure way". It extends the definition provided in the TEN-E regulation of 2013 [10] and highlights the importance of Information and Communication Technologies (ICTs) in managing the complex and dynamic nature of the electricity grid, especially in an environment that involves a high level of integration of RES.

As Smart Grids rely heavily on the use of ICTs, advanced metering infrastructure (AMI) and a huge number of various sensors, data protection and cyber security issues arise [11], [12]. This emphasises the need for standards to ensure energy systems' resilience, robustness and reliability, as well as increasing consumer confidence and acceptance of new technologies, and promoting demand-side services. In this context, Smart Grids can achieve their goals of sustainable and cost-efficient electricity distribution, while ensuring the security and privacy of user data.

Standards can provide a common framework, ensuring that the technologies and systems developed by different producers and innovators are compatible with each other. Given the range of technologies, producers and innovators involved, communication and cooperation to ensure standards development for efficient integration are vital. This fact is acknowledged by multiple researchers and practitioners, e.g., [6], [8], [13]–[16] and others.

An interesting overview of standardisation activities through the prism of energy system functionalities is provided in [15], concluding that despite significant work within Smart Grid standardisation, more efforts are needed to ensure interoperability and seamless operation of different technologies and sectors. This can be achieved only through cooperation of different stakeholders from policy makers to researchers and industrial players. In addition, [16] uncovers a gap between the conceptual thinking of scientific researchers and the more practical point of view of industry based on real life experience in standards development. Furthermore, three ways (modes) of standardisation are distinguished in [14]: committee-based, market-based and government-based. A multi-mode approach is likely to become increasingly important in the future particularly in developing 'smart' technologies and innovating large-scale complex systems like Smart Grids. In addition, [13] captures the complexity of the standards development environment for Smart Grids in comparison with other emerging technologies considering the multiple actors and layers involved. It emphasises that public sector researchers can make significant contributions to standards development, both at the earliest stages in a technology's maturity and later in the industrial lifecycle. This implies that more attention needs to be paid to involving researchers and innovators in standards development processes, particularly through publicly funded collaborative projects.

Standards serve as the linking connection among researchers, innovators and developers by systemising and disseminating knowledge, and offering validated processes and best practices. As such, standardisation contributes to information sharing and knowledge enhancement and also saves resources. Standardisation promotes also the scalability and replication potential as seen in [17]. By sharing findings, keeping knowledge open to the research and innovation (R&I) community and promoting synergies, standardisation is the key for further development of Smart Grids.

Several studies ([18], [19]) explore the motivation for industrial players to participate in standardisation processes. Firms participating is standardisation may benefit from knowledge sourcing, influencing the regulatory framework, accelerating the route-to-market of innovative products and accordingly increasing performance what is specifically true for manufacturing industries [19]. At the same time, literature [20] highlights that for researchers the main driver is intrinsic motivations and that reputation and financial rewards are not relevant.

European projects are a space where research meets innovation, industry, policy and real-life implementation. Standardisation supports transferring R&I outcomes into practical applications and solutions that can be used by society and industry. The increasing focus of European Framework Programs (Horizon 2020, Horizon Europe) on higher Technology Readiness Levels (TRLs) requires more attention to standardisation efforts for successful commercialisation. However, early evidence [21] suggests that the Program has only made limited progress in this dimension. The untapped potential of pre-normative research in support of standardisation in EU-funded projects is also acknowledged in the new EU Strategy on Standardisation [22]. To address this issue, the Commission has launched the European Standardisation Booster [23] aiming at providing expert services to European projects to help them increase and valorise project results by contributing to the creation or revision of standards.

The above considerations together highlight an urgent need to investigate how Smart Grid standardisation is addressed in European collaborative R&I projects. This is the research gap addressed in this paper.

The paper focuses on the role of EU R&I projects in Smart Grid standardisation. The contributions of this paper are twofold: firstly, we perform a high-level assessment of standardisation activities in dissemination, exploitation and communication (DEC) strategies of collaborative EU R&I Smart Grid projects; in addition, we estimate the contribution of R&I projects to standardisation. We put forward the following research questions:

1. What is the contribution of EU R&I projects to SG standardisation?
2. In which standardisation activities do collaborative EU R&I projects engage?
3. What are the factors influencing project engagement in standardisation process?

To answer our research questions, we analyse EU funded Smart Grid R&I projects. Our approach is described in detail in the Methodology Section. We then present an overview of the Smart Grid standardisation ecosystem to set the context of our study in Section 3. Results and Analysis are presented in Section 4, and finally conclusions and recommendations are presented in Section 5.

Although there has been significant progress in the development of Smart Grid technologies, standardisation efforts have not kept pace. Public funding plays a vital role in supporting standardisation initiatives. Promoting Standardisation efforts within EU projects, such as Horizon 2020 and Horizon Europe, is of paramount importance. Our study highlights that while there are some positive practices in including standardisation within the scope of R&I projects, there is still a need for further efforts to facilitate the involvement of R&I projects in standardisation.

2. METHODOLOGY

We focus on the Smart Grid domain in a broader understanding of the term, which includes consumer behaviour and social acceptance elements along with technical aspects. This section discusses our methodology to identify different pathways of how R&I projects could be involved in the standardisation process. Furthermore, it presents the sources used for data collection, the categories for classification of projects and limitations of the study.

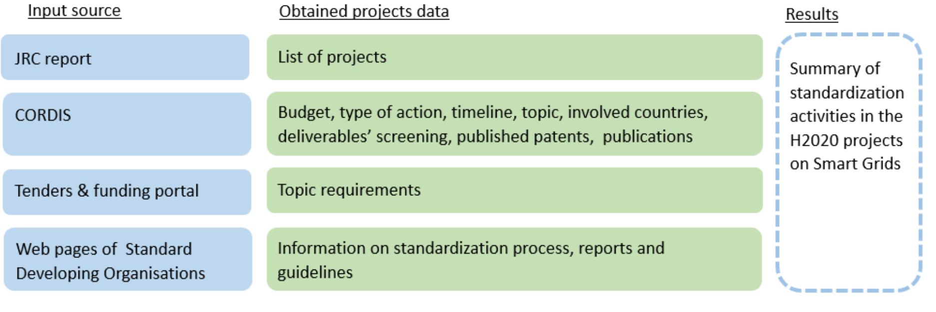

Fig. 1. Data sources used for the study.

Our analyses are based on the selection of Smart Grid projects identified in the Joint Research Centre (JRC) report [24] and complemented by additional data sources, i.e., CORDIS [25], EC Tenders & Funding Portal [26], websites of projects]specific and standardisation bodies (Fig. 1).

The JRC report [24] presents an overview of European R&I projects in the field of Smart Grid funded by the seventh EU framework programme (FP7), Horizon 2020 (H2020) and the competitiveness and innovation framework programme (CIP) in terms of funding, distribution between project domains and participating organisations. Our assessment is limited to projects funded under H2020, the project start date is between 2015 and 2020.

In order to identify projects, which included standardisation activities, we performed a manual check of relevant project results available in the CORDIS database [25] and on project specific web pages. It should be noted that some projects did not have sufficient information published for making conclusions on their activities related to standardisation, because they were at the earlier stages or for other unknown reasons. In these situations, we assumed that there was no link to standardisation activities, as generally projects tended to have references to standardisation in the first two years of project execution timeline if standardisation was a focus or key activity of the project.

To acknowledge the extent to which the projects had addressed standardisation, we defined four levels of possible contribution to standardisation activities and relevant criteria (see Table 1 inspired by [27]–[29].

Table 1. Summary of Criteria Used to Determine Project Level of Contribution to Standardisation

Level	Description	Criteria
n/a	Standardisation activities are not included in the project scope	None of the following criteria are met **or** The publicly available information on project results is insufficient
Level 1	Existing standards screening	A report on relevant standards is publicly available
Level 2	Influence ongoing standardisation	Project results are translated to the relevant TC at European or national level (national mirror group) **or** The project joined a Technical Committee through the project liaison concept **or/and** Project results are considered in standardisation document
Level 3	Elaboration of a new standard	The project initiated the development of a CENELEC Workshop Agreement (CWA) **or** The project proposed a new working item (WI)

Next, we used the EC Tenders & Funding Portal [26] for assessing requirements of relevant calls in terms of references to standardisation and necessary commitment. We anticipated that projects would demonstrate different levels of contribution to standardisation. Therefore, we proposed that the probability of a project being deeply engaged in standardisation work depended on existence of explicit requirements to do so in the relevant call.

Additionally, we gathered information on publications and intellectual property rights applications for all the projects in our selection to have an overview via other DEC options.

Results and analysis are presented in Section 4.

3. REVIEW OF THE SMART GRID STANDARDISATION

In this section, we provide a comprehensive overview of the Smart Grid Standardisation ecosystem and processes to set the context and highlight opportunities for the engagement of researchers and innovators.

3.1. Smart Grid Standardisation Ecosystem

This section highlights the complicated structure and diversity of actors in the Smart Grid Ecosystem. The ecosystem structure influences which activities researchers and innovators may engage in. Some insight into the activities of major players contributing to Smart Grid standards development and its taxonomy is provided below.

Standards are developed by different entities:

- **Formal standards** are developed by officially recognized bodies – formal Standard Developing Organisations (SDOs). Based on Regulation (EU) No 1025/2012 [30], the **European Committee for Standardisation (CEN), the European Committee for Electrotechnical Standardisation (CENELEC)** and the **European Telecommunication Standards Institute (ETSI)** are the three European Standardisation Organisations that are competent in the area of voluntary standardisation for Europe. The international equivalents of CEN and CENELEC are **the International Organization for Standardisation (ISO)** and **the International Electrotechnical Commission (IEC)** respectively. SDOs cooperate on European and global levels, some agreements allow publishing of dual logo standards, e.g., ISO/IEC 14543 series on Information technology – Home electronic system architecture.
- **Informal standards** are developed by various forums and consortia – informal SDOs, many of which are very well known and highly respected, e.g., **Institute of Electrical and Electronics Engineers Standards Association (IEEE SA).** These standards are usually initiated by industries and are based on specific technology and market needs representing probably more dynamic part of standardisation work. These standards are often voluntary and can be further ratified by formal SDOs.
- **Private or industrial standards** (sometimes referred to as proprietary) are developed, maintained and controlled by a licence agreement which is owned by a specific company or groups of companies. Proprietary standards may be free to use, but the file specification is often undisclosed. These standards can be in some cases competitive. Sometimes battles between different technologies result in de-facto standards [14].

In 2009, the European Commission (EC) and the European Free Trade Association (EFTA) mandated **CEN, CENELEC** and **ETSI** with responsibility for the development of an open architecture for utility meters involving communication protocols enabling interoperability (smart metering). In response to this request (M/441[31]), CEN, CENELEC and ETSI established the Coordination Group on Smart Meters (CG-SM). Then, in response to requests issued in March 2011 by the EC and EFTA to develop standards for Smart Grids under EC mandate M/490 [32], CEN, CENELEC and ETSI established a Smart Grid Coordination Group (SG-CG). SG-CG worked intensively and produced several important reports. An interesting report with quite an impact [33] proposed a widely acknowledged reference architecture for Smart Grids – Smart Grids Architecture Model (SGAM) taking on board the complexity and the different layers of the Smart Grid. The SGAM framework introduced among others interoperability aspects and expanded from technical and component domains to business and ICT domains in a layer-based approach that brings all these together. Also, this entity developed a set of standards [34], supporting the wider adoption of Smart Grids in Europe. Since 2016, the firstly formulated entity changed to Coordination Group on Smart Energy Grids (CG-SEG), which took over and extended the responsibilities [35]. In addition, they have provided standardisation requirements within the framework of adoption of the Clean Energy Package (CEP) [36]. Since 2021, CG-SM was merged in CG-SEG, which continues to advise on European standardisation requirements on Smart Grids and multi-commodity smart metering standardisation, including interactions between commodity systems (e.g., electricity, gas, heat, water).

Multiple **CENELEC** Technical Committees (TCs) develop standards that help energy grids improve their safety, reliability and flexibility. TC 57 "Power systems management and associated information exchange" in collaboration with the IEC TC 57 develops key standards for Smart Grid technologies and their integration with existing power grids. Another example is TC 8X "System aspects of electrical energy supply", which developed EN 50549 series on Requirements for generating plants to be connected in parallel with distribution networks supporting the Commission Regulation 2016/631/EU [37]. These are important standards as they serve as a technical reference for connection agreements between Distribution Grid Operators (DSOs) and electricity producers. Other organisations and their area of focus are summarised in Appendix A.

Several ETSI committees are involved in standards development useful for Smart Grids. With strong support from the Commission and in close interaction with industry [16] ETSI SmartM2M TC has developed and continues to enhance the Smart Applications REFerence (SAREF) ontology, which aims at enabling semantic interoperability between solutions from different providers and within various activity sectors (i.e., energy, environment, building, smart cities, industry and manufacturing, and smart agriculture) in the Internet of Things (IoT).

On a global level, the **IEC** established a System Committee (SyC) for Smart Energy that aims at providing systems level standardisation, coordination and guidance in the areas of Smart Grids and smart energy, including interaction in the areas of heat and gas. The committee has developed and published a Smart Grid Standardisation Roadmap IEC TR 63097 that presents the standardisation requirements of a Smart Grid based on the technologies and systems that are its building blocks. Under this approach, an exhaustive list of standards is developed and they are examined under the prism of the different operations of the Smart Grids.

A number of standards have horizontal effect and are used for all operations and thus considered as core standards (IEC 61850 on power utility automation, IEC 61508 on functional safety of electrical/electronic/programmable electronic safety-related systems, IEC 61970 on common information model (CIM)/energy management, IEC 61968 on CIM/distribution management, IEC 62056 on data exchange for meter reading, tariff and load control, IEC 62351 on security, IEC TR 62357 on reference architecture) [38].

Additionally, the IEC moved one step further by providing a visualised Smart Grid Standards map [39]. This is an online user-friendly tool that facilitates the user to spot standards as per the technologies and the different systems as these are represented into the SGAM plane. The IEC works in close collaboration with the ISO through a technical joint committee to develop standards relating to ICT that is catalytic for the Smart Grid.

ISO has set up several TCs to deal with standards that are highly relevant with the Smart Grid standardisation. For example, ISO/TC 205 "Building environment design" works on the standardisation of the holistic assessment of the energy performance of new and existing buildings taking on board also RES, energy efficiency, energy performance and different carriers as well. ISO 17800:2017, developed within this TC, provides the basis for common information exchange between control systems and end use devices. As such, it provides a baseline for energy consumers that supports a wide range of concepts that are foreseen in the Smart Grids such as demand response, load shedding, peak shaving etc.

As already mentioned, standardisation leverages voluntary work coming from the industry sector. As such, different industrial alliances, i.e., informal SDOs, developing standards highly relevant to Smart Grid have been set up. Some of recognised organisations are described further.

The **IEEE SA** is a leading global community that develops standards for different technical systems including Smart Grids. It has developed under this domain more than 100 standards [40], including 10 standards named in the Smart Electric Power Alliance (SEPA) Smart Grid Catalogue of Standards [41], which aims at serving as a useful resource for utilities, manufacturers, regulators, consumers and other stakeholders globally. Among the broad number of systems and technologies addressed by IEEE standards are cyber security (IEEE C37.240, IEEE 1711 series) distributed energy resources (DER) (IEEE 1547 series), Smart Grid interoperability (IEEE 2030 series), substation automation (such as IEEE 1815 on Distributed Network Protocol (DNP3)) and others.

Another well-known association involved in Smart Grid standardisation is the **International Telecommunication Union (ITU)** – the United Nations specialized agency for information and communication technologies (ICTs). Several ITU-T study groups (SGs) are working on Smart Grid related topics and developing international standards known as ITU-T Recommendations in the areas of IoT, Machine-to-Machine (M2M), home energy management systems, smart metering, intelligent transportation systems and others. For example, the ITU-T SG15 "Transport, Access and Home" developed standards on power line communication (ITU-T recommendations G.990x-series), which is one of the most important technologies for Smart Grid.

The Internet Engineering Task Force (IETF) is developing voluntary standards for the Internet that are often adopted by Internet users, network operators, and equipment vendors. IETF RFC 6272-2011 on Internet Protocols for the Smart Grid is listed in [41].

Open Automated Demand Response (OpenADR) standardizes Demand Response (DR) and DER related issues to enable stakeholders such as operators, aggregators and customers to cost-effectively manage and participate in related activities. OpenADR development represents a unique experience of how standards evolved through research, pilots, commercialization, specification development, informal standard development and, finally, to establishment of the **OpenADR Alliance** to create a formal standard and certification and testing program [42]. The important contribution of OpenADR Alliance is acknowledged by the IEC. It has approved the OpenADR 2.0b Profile Specification as a full IEC standard, to be known as IEC 62746-10-1 on systems interface between customer energy management system and the power management system.

Another interesting example is **EEBus** that emerged from the E-ENERGY lighthouse project funded by Germany's Federal Ministry of Economic Affairs and Climate Actions (BMWK) to **EEBus Initiative e.V.** The EEBus Initiative e.V. is the non-profit association that manages and supports the standardisation of EEBUS. EEBUS is a protocol suite for the IoT that aims at standardising the interface between electrical consumers, producers, storage and energy management systems. The EEBus Smart Premises Interoperable Neutral Message Exchange (SPINE) specification and Use Cases are published in EN 50631-1 on household appliances network and grid connectivity. Other standardisation activities are ongoing [43].

KNX Association is a non-profit-oriented organisation which develops and promotes the KNX standard for smart home and building solutions. KNX is approved as ISO/IEC 14543 on Home Electronic Systems (HES) architecture as well as EN 50090 on Home and Building Electronic Systems and EN 13321-1 on open data communication in building automation, controls and building management.

This overview of the different bodies highlights how complex the Smart Grid standardisation ecosystem structure is, and how unclear the relations among the different standards bodies are. This compounds the inherent complexity of such a concept as the Smart Grid that touches upon different domains of technology and innovation.

3.2. Standardisation Processes

Having introduced the bodies involved in Smart Grid Standardisation, we next describe the standardisation process, the types of deliverables and the approval processes so that we can understand the opportunities for researchers and innovators to participate.

Standardisation deliverables fall into the following general categories:

- A **European Standard** provides rules, guidelines or characteristics for activities or their results, for common and repeated use and is identified by a unique reference code, which contains the letters 'EN'. The national members of CEN and CENELEC have an obligation to adopt all full European Standards as national standards and to withdraw any conflicting national standards that are in their catalogue. The development of the European Standards follows strict procedure and might take up to 36 months from an idea to publishing. Although any interested party can introduce a proposal for new work – **New Work Item** proposal, the work is usually promoted by the members. Once the proposal for a standard has been evaluated and approved, the proposal goes on to the drafting stage. When the draft standard is finalized, it is released for public comment and vote, a process known as the 'enquiry'. During this stage, everyone who has an interest may comment on the draft. Then, the votes and comments on the standard are evaluated and depending on the result, the draft standard is either published or updated and subsequently submitted to 'formal vote' stage for SDOs members to submit their vote and comments. If the result of the vote is positive, the standard is finalised and published. A European Standard adopted on the basis of a request made by EC for the application of Union harmonization legislation makes a **Harmonized Standard**. The references of harmonised standards are published in the Official Journal of the European Union (OJEU).

- A **Technical Specification** is close to the full standard in terms of detail, but has not yet passed through all approval stages. It is the option for setting specifications for evolving technologies because full standardisation could be seen as premature. It is a normative document, meaning that it contains requirements which must be met in order for claims of compliance with the standard to be certified. Technical Specifications are subject to optional national adoption.
- A **Technical Report** is an informative document that provides information on the technical content of standardisation work, i.e., data, measurement techniques, test approaches, case studies and methodologies. In contrast to a technical specification it does not contain any requirements. It is approved within the relevant Technical Committee. Technical Reports are subject to optional national adoption.

The Standards deliverables are developed and published by different formal and informal SDOs using various degrees of consensus in their preparation and approval, meaning that the standards published are selected and agreed by industry and stakeholders in the area and not by the organisations themselves. In case of **formal** SDOs, the approval process usually operates through national representation, rather than through organisation or individual representation. Thus, discussions within the Technical Committees of CEN and CENELEC are based on inputs by national delegations who represent the views expressed by the related groups at the national level, the national mirror groups. These mirror groups at the national level are composed of voluntary experts and stakeholders that take direct part in the writing of the standards.

In contract, ETSI is structured differently and operates by direct participation – ETSI members are not representatives of national delegations or other bodies, but mostly represent industrial companies and organisations. ETSI standards are developed by Technical Committees or other types of working groups, made up of ETSI members.

Furthermore, CEN and CENELEC offer a possibility for organisations to apply for status of Partner or Liaison Organisation [44]. R&I projects can be granted **Liaison Organisation** status for duration of the project, providing the consortium an opportunity to participate as an entity in the TC without voting rights.

Thus, R&I projects can contribute to the development of European Standards by individual partners being involved in the work of the TC, the national mirror group or by joining relevant TC as a project liaison.

As a faster pathway into standardisation and in support of innovative technologies, CEN and CENELEC have added the **CEN and/or CENELEC Workshop Agreement (CWA)** [45] to their portfolio of publications. A CWA is developed and agreed by the participants in CEN and/or CENELEC

Workshop. Participation is open to all stakeholders. A CWA is produced quickly (up to 12 months) to address specific market requirements in areas, which are not the subject of more formal standardisation. Therefore, it might serve as a good option for R&I projects, which have to deliver results within a limited timeframe. Moreover, there is also a possibility to indicate the participants and their organisations in the CWA foreword, in this way increasing the project visibility. The CWA can be considered the first step to a European Standard. If relevant, it may be proposed for conversion into the European Standard. In case it is approved by the Technical Committee, the CWA will have to go through the full standard development process and follow the rules for the development of European Standards.

4. RESULTS AND DISCUSSION

Having described the standardisation ecosystem and identified opportunities for participation, we next identify the contribution of EU R&I projects to SG standardisation to date, uncover in which standardisation activities collaborative EU R&I projects engage, and identify the factors influencing project engagement in standardisation processes.

4.1. General Findings

Based on [24], we identified 225 projects funded under 59 topics (calls) of H2020 with a total budget of 1.89 billion EUR, which includes Coordination and Support Actions (CSA), Research and Innovation Actions (RIA) and Innovation Actions (IA) (see Fig. 2).

	CSA	RIA	IA	Totals
Number of projects	36	71	118	225
Total investment	70.46 million EUR	284.21 million EUR	1.53 billion EUR	1.89 billion EUR
EU contribution	70.35 million EUR	279.63 million EUR	1.20 billion EUR	1.89 billion EUR
Number of projects addressing standardization	0	19	29	48
Share of projects addressing standardization	0	27 %	25 %	21 %

Fig. 2. Overview of H2020 Smart Grid projects.

IAs constitute the biggest share of projects in terms of number (32 %) and in terms of funding (77 % of EU funding). IAs aim at producing plans and arrangements or designs for new, altered or improved products, processes or services and may include prototyping, testing, demonstrating, piloting, large-scale product validation, market replication and only limited research and development activities [46]. Whereas, RIAs aim at establishing new knowledge and/or to exploring the feasibility of a new or improved technology, product, process, service or solution and include basic and applied research, technology development and integration, testing and validation on a small-scale prototype in a laboratory or simulated environment and only limited demonstration activities [46]. Thus, RIAs are expected to have results with lower maturity – TRL2 to TRL6 depending on a specific topic, while IAs are usually intended to produce results with higher maturity and closer to implementation – TRLs between 6 and 8.

Our general overview uncovered that out of 48 EU projects (21% from our selection of 225 addressed standardisation activities), 19 were RIAs and 29 were IAs. We note that in relative numbers – the share of projects which include standardisation related activities is similar for RIAs (27 %) and IAs (25 %). We analyse this further to understand the level of contribution to development of new standards of the IAs and RIAs projects separately.

As for CSAs, these consist of accompanying measures such as standardisation, dissemination, awareness-raising and communication, networking, coordination or support services, policy dialogues and mutual learning exercises and studies, including design studies for new infrastructure. CSAs may also include complementary activities of strategic planning, networking and coordination between programmes in different countries [46]. In our analysis, none of the CSAs addressed standardisation development or innovation.

4.2. Standardisation Related Project Outcomes

Next, we manually checked relevant deliverables of projects addressing standardisation and extracted information on the level standardisation covered. Thus, using the proposed criteria described in the Methodology Section (Table 1), we estimate the level of contribution to standardisation activities. Figure 3 summarises the obtained results.

Level of contribution to standardization	RIA	IA	Totals	RIA	IA	Totals
Level 1 – standards screening	11	18	29	58 %	62 %	60 %
Level 2 – influence ongoing standardization	7	8	15	37 %	28 %	31 %
Level 3 – elaboration of a new standard	1	3	4	5 %	10 %	8 %
Totals	19	29	48	100 %	100 %	100 %

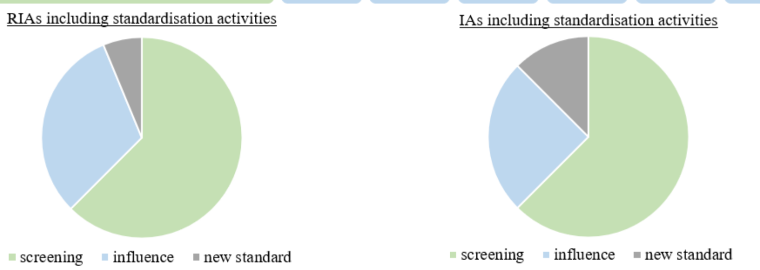

Fig. 3. Contribution to standardisation of H2020 smart grid projects.

Of the 48 projects, 29 (60 %) are involved in Level 1 "Screening", 15 (31%) are involved in Level 2 "Influencing", while four (8%) are involved in Level 3 "Elaborating a new standard".

As mentioned above, the percentage of projects which include standardisation related activities is similar for RIAs and IAs

(Fig. 2). The shares of projects participating in standards development process, screening at 11/19 (or 58 %) for RIAs and 18/29 (or 62 %) for IAs are similar. Going beyond pure standards screening for project purposes and aiming to influence standards are similar both for RIAs (7 of 19 or 42 %) and IAs (8 of 29 of 38 %). This confirms that R&I projects in favourable circumstances can respond to the need for proactive standardisation at a point before the technology matures [47].

Therefore, we are curious if the level of contribution depends on the type of action. Our analysis confirms that IAs are more associated with initiating new standards development, being twice as likely (10 %) than RIAs (5 %) to be involved in Level 3 "Elaborating a new standard". This in line with expectations that the standardisation requires a certain maturity level of relevant technology.

As for project contribution to standardisation topics, we use domain definitions as introduced in [24]. We identified a single main domain for each project involved in Level 2 "Influencing" and Level 3 "Elaborating a new standard". The biggest input to standards development was made by projects focusing on Demand-side management, Smart network management and Other domains. Remaining domains, including E-mobility, Smart cities, Integration of distributed generation and storage and Integration of large-scale RES and storage, were addressed less frequently. It shall be noted that interoperability issues, including information models and relevant use cases, dominate linked standardisation activities across all domains.

4.3. PROJECT PATHWAYS TO STANDARDISATION

Table 1 summarises the contribution to standardisation activities of projects at Levels 2 and 3, which go beyond pure standards screening, highlighting the main outcomes and partner involvement. Four projects of our selection (SUCCESS, SMARTER TOGETHER, WiseGrid, InterConnect) initiated the elaboration of new standards. SMARTER TOGETHER and WiseGRID succeeded in the creation of CWAs: CWA 17381 on good practices for Smart City solutions [48], CWA 17382 on sustainable energy retrofit process management [49] and CWA 50714 on reference model for distribution application for microgrids [50]. SUCCESS initiated development of a new ETSI Technical Report [51] on smart meter security, whereas InterConnect initiated a development of preliminary Working item (PWI) on Digital Twin use cases [52]. WiseGrid was also nominated for the Standards+Innovation Awards by CENELEC in 2020 [53].

Furthermore, we identified two projects referred in European standards texts, i.e., FLEXICIENCY is referred in IEC 62325-451-10:2020 on the framework for energy market communications [54] and TDX-ASSIST is referred in IEC 61968-13:2021 on system interfaces for distribution management [55]. According to [56], including scientific papers in Standards bibliographies is not common. This highlights the significance of the contribution of the FLEXICIENCY and TDX-ASSIST projects. Furthermore, WiseGRID and TDX-ASSIST are included as best practice examples in the relevant study published by the Commission [57].

Other projects might be also refereed in the Standard's bibliography. However, bibliography analysis is not included in the scope of this study as in many cases this requires access to standardisation document databases, which may incur financial costs.

We next explore how the projects engaged in the standardisation process. The vast majority of projects concentrated their effort in support of development of formal standards by contributing to the work of IEC and ETSI. Some of these provided their inputs to the IEC through the National Standardisation Bodies: The Slovenian Institute for Standardisation (SIST) (FutureFlow), Finnish National Electrotechnical Standardisation Organisation (SESKO) (DOMINOES), Croatian Standards Institute (HZN) (FLEXCoop), the Spanish Association for Standardisation (UNE) (GREENSOUL, USER-CHI and WiseGRID). UNE also participated as a project partner in WiseGRID and USER-CHI UNE. It shall be noted that only one project from our selection (PROMOTioN) used an opportunity and became a liaison partner of CENELEC TC.

Table 2. Contribution of EU Funded Horizon 2020 Smart Grid Projects to Standards Development

#	Project acronym Timeline Topic ID action type	Technical Committees / working groups of SDOs in which project partner(s) are involved	Standardisation Outcomes
Level 2 – Influence			
1	FLEXICIENCY 2015–2019 LCE-07-2014 IA	no information	Defining a common data model and communication protocol also for B2B interactions – EUropean Meter Exchange Data (EUMED) CIM [59]. Project's contribution taken on board by CG-SEG [36]. Project is referred in IEC 62325-451-10:2020 on the framework for energy market communications [54].
2	FHP 2016–2019 LCE-01-2016-2017 RIA	no information	Project participated in EEBus technical discussions trying to standardise the heat pump direct control/advice use case [60].
3	FutureFlow 2016–2019 LCE-06-2015 RIA	The Slovenian Institute for Standardisation (SIST) TC/PSE "Process systems in energy sector" [61]	Standardisation findings and amendments to the Smart Grid Reference Architecture (SGRA) presentation to SIST, contribution of Use Case descriptions and template to Smart Grid Use Cases repository through the IEC National Committee of Slovenia represented by SIST [61].
4	Storage4Grid 2016–2020 LCE-01-2016 RIA	IEEE-SA, IEC TC77/SC77A/WG9 "Power Quality measurement methods", TC38/WG 55 "Uncertainty evaluation in the calibration of Instrument Transformers", IEC SyC LVDC/OF Open Forum 1 "Platform for open exchange of technologies, innovations, challenges in LVDC", IEC SyC LVDC/WG 1 "LVDC Standards for Electricity Access", IEC TC8/JWG12 "Requirements for measurements used to control DER and loads", Portuguese national technical commission for electrotechnical standardisation (IPQ) [62]	Partners contributed to various activities within mentioned working groups [62].

5	PROMOTioN 2016–2020 LCE-05-2015 IA	IEC WGs (IEC TC88 WG27 "Wind turbines – Electrical simulation models for wind power generation" and other), IEEA-SA WGI10 "HVDC", project became a liaison partner of CENELEC TC8X WG06 "Generic Smart Grid Requirements" [63]	Recommendations on harmonization of wind power plants (WPPs) connected to HVDC systems [64], recommendations on harmonisation of HVDC Systems [65]. Active contribution to CLC/TS 50654-1:2020 on HVDC Grid Systems and connected Converter Stations as a liaison partner of CENELEC TC8X WG06 [65].
6	CATALYST 2017–2020 EE-12-2017 IA	OpenADR Alliance, IETF, British Standards Institution [66]	Recommendations on ISO/IEC 30134 on Data Centres Sustainable Heat Exploitation (SHE) and Reuse of Waste Heat, or Heat Usage Effectiveness (HUE) KPIs standardisation [66].
7	DEFENDER 2017–2020 CIP-01-2016-2017 IA	Slovenian National Institute for Standardisation (SIST) Expert Board for standardisation in areas of electrotechnics, information technology and telecommunications [67]	Suggestions for improvements in information security standards, specifically, ISO 27000, ISO-IEC 27001, ISO-IEC 27002 on security, ISO-IEC 27019 [67].
8	TDX-ASSIST 2017–2020 LCE-05-2017 RIA	European Network of Transmission System Operators for Electricity (ENTSO-E) is one of projects partners and is a liaison partner with several of IEC TC57 WGs [68].	Recommendations on novel updates and extensions to CIM, feedback on tools used for Use Case development, contribution of a Use Case repository towards IEC SyC Smart Energy, project partners participated in some IEC meetings [69]. Project's contribution taken on board by CG-SEG [36]. Project mentioned as best practice example in [57]. Project is referred in IEC 61968-13:2021 on Application integration at electric utilities – System interfaces for distribution management [55].
9	DOMINOES 2017–2021 LCE-01-2016-2017 RIA	Finnish National Electrotechnical Standardisation Organization (SESKO) committee SK8 "Systems aspects for electrical energy supply", SESKO's committee SK69 "Electrical road vehicles and industrial trucks" [70].	Project partners participated in IEC SyC LVDC, SESKO's SK8 and SK69 meetings [70].
10	FLEXCoop 2017–2021 LCE-01-2016-2017 RIA	IEC TC 57 mirror committee of Croatian Standards Institute (HZN)[71].	Project partners participated in activities to adopt the OpenADR 2.0b within the IEC 62746 providing recommendations on standardizing the functions of flexibility infrastructure and cybersecurity [71].
11	HOLISDER 2017–2021 EE-12-2017 IA	OpenADR Alliance, IEC TC 57 - WG 21 "Interfaces and protocol profiles relevant to systems connected to the electrical grid" and WG 17 "Power system intelligent electronic device communication and associated data models for microgrids, distributed energy resources and distribution automation", CENELEC TC205/WG18 "Smart grid, ETSI oneM2M [72]	Recommendations on IEC 61850 Series on Communication Protocols, IEC 62746 series on Systems and Interfaces between customer EMS and power management systems, Open ADR 2.0, SAREF [72].
12	EU-SysFlex 2017–2022 LCE-04-2017 IA	no information	Proposal for data exchange standards and protocols [73]. Project's contribution taken on board by CG-SEG [36].

13	DRIMPAC 2018–2022 EE-12-2017 IA	IEC, CEN/CENELEC (working groups are not specified), OpenADR Alliance and ETSI oneM2M [74]	Planned to provide extensions to OpenADR and oneM2M [74].
14	GREENSOUL 2019–2019 EE-11-2015 RIA	Committee CNT178 “Smart Cities” of the Spanish Association for Standardisation (UNE) [75]	Contribution to the developments done with the Universal Monitoring Device and software with the NT178 WG Semantic in Smart Buildings [75].
15	USER-CHI 2020–2024* LC-GV-03-2019 IA	One of project partners – the Spanish Association for Standardisation (UNE) – is a member of CEN-CENELEC and of ISO-IEC as the National Standardisation Body [76]	Pending contribution to standardisation activities.
Level 3 – Elaboration of a new standard			
1	SUCCESS 2016–2018 DRS-12-2015 RIA	ETSI TC Cyber [77]	ETSI TR 103 644 “CYBER; Increasing smart meter security” [51].
2	SMARTER TOGETHER 2016–2020 SCC-01-2015 IA	no information	CWA 17381 “The Description and Assessment of Good Practices for Smart City solutions” [48] CWA 17382 “Sustainable Energy Retrofit Process Management for Multi-Occupancy Residential Buildings with Owner Communities” [49].
3	WiseGRID 2016–2020 LCE-02-2016 IA	One of project partners is the Spanish Association for Standardisation (UNE), which as the National Standardisation Body is a member of CEN-CENELEC and of ISO-IEC [78]	CWA 50714 “Reference model for distribution application for microgrids” [50]. Project included in [57]. Project was nominated for the Standards+Innovation Awards by CENELEC in 2020 [53].
4	InterConnect 2019–2024 * DT-ICT-10-2018-19 IA	ETSI ISG CIM, ETSI oneM2M, ETSI SmartM2M, CLC TC 59X – WG07 “Smart house”, CLC TC 205 – WG19 “Adhoc group on Energy management ontology”, CLC TC 205 – WG18 “Smart Grids”, ISO/IEC JTC1, IEC TC 69 [52]	Pending contribution to SAREF suite of ontologies (i.e., ETSI SmartM2M working items DEN/SmartM2M-123158 “SAREF Guidelines for IoT Semantic Interoperability”, DTR/SmartM2M-103781 “Study for SAREF ontology patterns and usage guidelines” and other) contribution to EN 50631 on a household appliances network and grid connectivity (primary use cases (PCUs from InterConnect German pilots), EN 50491-12-2:2022 on general requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS), ISO/IEC 21823-3 on IoT [52]. PWI JTC1-SC41-6 “Guidance for IoT and Digital Twin use cases” [52].

* The project is not finished, analysis is based on publicly available deliverables at the time of the study.

In summary, projects tend to engage in standardisation activities by being involved in ETSI TCs, IEC WGs or national mirror groups. This entails engaging in the standardisation process itself. Elaborating a CWA seems to be the easiest way for initiating a new standard. Meanwhile, becoming a liaison partner seems to require more resources and is underused by EU projects.

4.4. FACTORS FOR ENGAGEMENT IN STANDARDISATION

Next, we explored how the need of Smart Grid standardisation is addressed in funding calls and how these expectations are incorporated into project activities. We checked topic texts in order to understand if these included any references or explicit requirements to include standardisation activities in the project scope. We analysed projects funded under 59 different topics of H2020. It should be noted that 19 of these topics included references to standardisation using different wording, e.g., "solutions should be compatible with open standards", "include a detailed analysis of current standards", "explore the need for further standardisation", "demonstrate a good knowledge available or emerging standards", "demonstrate interoperability (e.g., through standards, protocols, regulatory framework)", etc.

In total, 70 projects were funded under these specific topics and 39 projects (56 %) included in their scope standardisation activities according to our identified criteria (Table 1). On the other hand, we identified only nine projects addressing standardisation out of 155 projects funded under other topics, which highlights that unless standardisation is explicitly included in the call, it is unlikely to be addressed in the proposals or funded projects.

Results are presented in Fig. 5. Hence, it seems that projects are more likely to include standardisation activities if it is mentioned in the call text. However, deeper contribution might be expected in case of explicit requirements in the call.

	Calls with reference to standardization	Calls with no reference to standardization
Total number of calls	19	40
Total number of funded projects	70	155
Total number of projects including standardization activities	39	9
Number of projects including elaboration of a new standard	3	1

Fig. 5. Overview of H2020 Smart Grid related funding calls and related projects in terms of refrence to standardisation.

Additionally, we conducted a concise analysis of project budgets. Due to the substantial variation in budgets across different projects, including factors such as the type of action, call requirements, scale of demonstrations, and technologies involved, it is challenging to draw definitive conclusions regarding the financial aspect. Nonetheless, our objective was to gain a high-level understanding of the financial allocations. We noticed that projects, which involved activities resulting in the elaboration of a new standard, tended to have higher than average budgets (the average budget of all analysed RIAs was 4 million EUR, whereas the average budget of IAs was 12.98 million EUR). Involvement in the standardisation process might require additional resources, which should be foreseen during the planning stage of a European project. Therefore, potential project participants should evaluate the efforts needed as well as be aware of the benefits the project might get by being actively involved in the standardisation process.

Finally, we examined the geographic distribution of participants involved in the projects, which included active involvement in standardisation, i.e., at Levels 2 and 3 influencing or elaborating a new standard (Annex A). For the purpose of our analysis, we adopted the definition of "participation" as provided in [24], wherein it is defined as the involvement of a single organisation in a single project.

The geographical distribution of participations revealed differences between countries, with Spain, Italy and Germany emerging as the frontrunners in terms of the number of participations in Smart Grid projects showcasing good examples of addressing standardisation (Fig. 6). The same countries are identified as leaders in Smart Grid related projects in terms of both participation and shares of EU contribution in [24]. Hence, it seems that more successful countries in H2020 tend to demonstrate more involvement in standardisation activities in the frame of European projects.

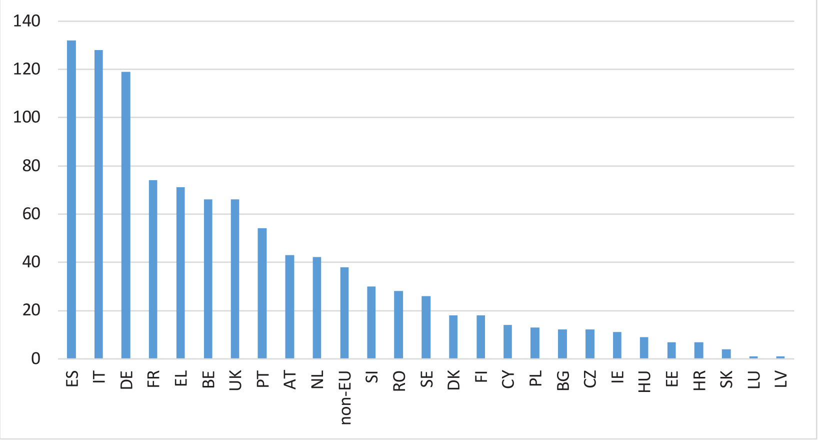

Fig. 6. Geographical distribution of participations.

Moreover, 10 of 19 projects demonstrating active involvement in standardisation are coordinated by organisations from the above-mentioned three countries – Spain, Italy and Germany. Typically, when project activities included engagement with National Standardisation Bodies, the coordinator often hailed from the same country as the respective National Standardisation Body. This alignment highlights the role of project coordinator in facilitating effective communication and collaboration between the project and standardisation organisations.

Standardisation can be seen as a means of implementing and disseminating the research results. For example, ref. [58] defines publishing, patenting and standardisation as alternative forms of knowledge disclosure practices and looks into interlinks between these. It concludes that publishing and patenting, and patenting and developing standards, are substitutes, whereas there are no tensions between publishing and standardisation [58]. In this light, we also briefly examined how deeply Smart Grid projects are involved in publishing and patenting.

Projects from our selection produced in total 3953 publications, 1034 of which are peer-reviewed (almost five peer reviewed publications per project in average). As for Intellectual Property Rights (IPR) applications, so far, a limited number of IPRs are attributable to our selection of projects, i.e., according to CORDIS [25] data, eight patents have been granted until now. However, the number is not final, as the patenting process might take longer time. Thus, it seems that despite several good practices of capitalising on standardisation related activities, this pathway to valorise project results is not fully exploited.

5. CONCLUSION

A multi-mode approach is needed to facilitate the development of Smart Grid standards that connects researchers to industry practitioners. As shown in our analysis, EU funded public sector researchers can make and have made significant contributions to standards development through all stages of a technology maturity and industrial lifecycle. In this study, we have identified 21 % of EU Horizon 2020 Smart Grid projects that actively contributed to Smart Grid standardisation at different levels of understanding, influencing and elaborating new standards. We have identified which standardisation activities and smart grid domains such projects engage in, and explored the factors influencing engagement of such projects in Smart Grid standardisation processes.

Our study highlights the complexity of the Smart Grid standardisation ecosystem and shows that there are practical opportunities for funded research project partners to contribute to Smart Grid standardisation in a meaningful way. Our analysis also shows that specifying standardisation issues in the topic description can be a useful mechanism to ensure that standardisation needs and requirements are included into the project content and activities. We recommend such an action to ensure this opportunity is not missed.

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