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QualyGridS

Deliverable Report

Analysis, recommendations and roadmap at the European level

(D6.5)

www.QualyGridS.eu

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Author (Partner):	Valérie Seguin (CEA), Regine Reißner (DLR)	Approved (Coordinator):	Regine Reißner (DLR)
Other Authors:		Released (Coordinator):	Regine Reißner (DLR)
Approved (Partner)	Ben Green (ITM) Marcus Newborough (ITM) Pablo Marcuello (IHT) Christoph Imboden (HSLU) Laura Abadía (FHA) Regine Reissner (DLR) Shi You (DTU) Lennart de Waart (NEN) Marcus Bornstein (NEL)	Date of first issue:	15.07.20
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Abbreviations and Indices

Abbreviation	Explanation
WE	Water Electrolyser
ALK	Alkaline, reference to Alkaline Water WE technology
PEM	Proton Exchange Membrane, reference to PEM WE technology
BOP	Balance of Plant
RES	Renewable Energy Sources
TSO	Transmission System Operator
DSO	Distribution System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
FCR	Frequency Containment Reserve
aFRR	automatic Frequency Restoration Reserve
mFRR	manual Frequency Restoration Reserve
RR	Replacement Reserve
CAPEX	Capital expenditure
OPEX	Operational expenditure
LCOH	Levelized Cost of Hydrogen
EEG	Erneuerbare Energien-Gesetz (renewable energy regulation) in Germany
WP	Work Package
KPI	Key Performance Indicator
ISO	International Organization for Standardization
TC	Technical Committee
NWIP	New Work Item Proposal
IEC	International Electrotechnical Commission
JRC	Joint Research Center

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1 Introduction

The objective of this deliverable is to draw recommendations and propose an implementation plan for the deployment of WE providing grid services.

The first section gives an overview of the work conducted in the scope of QualyGridS project and describes the key targeted audience for the dissemination of the project.

The next two sections detail the main results on technical and economic aspects obtained through the project and the associated recommendations.

The fourth section describes all the actions related to the standardization effort for the test protocol and its dissemination.

As a conclusion, the last section summarizes the main recommendations and suggests an implementation plan.

2 Overview of the work conducted in QualyGridS project

2.1 Global overview of the work

Work performed in QualyGridS project aimed at favouring the deployment of WE providing services to the electrical grid.

The goal of the project was thus to define a standard test protocol for WE performing grid services. This test protocol should demonstrate the capability of the WE to meet grid services requirements, whatever the European country considered.

The definition of this protocol has been challenging because although the general principles of the grid services are similar throughout Europe, their precise implementation and the technical requirements they imply differ from one country to another.

During the project, a test protocol have been defined in WP2 of the project. This test protocol has been used to test several WE systems in WP2, WP3, WP4 & WP5.

	DTU	DLR	FHA	IHT	NEL
WE Manufacturer	ITM	Hydrogenics	IHT	IHT	NEL
Nominal Power as tested in QualyGridS	35kW	30kW	10kW	50 KW	300kW
WE type	PEM	PEM	Alkaline	Alkaline	Alkaline
BOP power	<1kW	<9kW	3.3kW	<1kW	2-3kW
Supply voltage	3 x 400V,50Hz	3 x 400V,50Hz	3 x 400V,50Hz	3 x 400V,50Hz	3 x 400V,50Hz
DC stack voltage	0-13V	0-17	0-18 V	0-16 V	0-250V
DC Stack current	0-3000A	0-3000A	0-3500A	0-10.000A	0-1600A

Table 1. Basic electrical parameters of QualyGridS test benches

These test campaigns helped to refine/adjust the test protocol. They also provided interesting learnings on the technical capabilities of state of the art WE to provide grid services and gave the manufacturers the information if there were gaps to be closed by developmental work.

In the meantime, an economic analysis has been performed in WP6 to identify and study in details positive business cases for WE producing hydrogen and offering services to the grid.

2.2 Key audience for project dissemination

QualyGridS project outcomes can be particularly interesting for several kinds of shareholders:

- For TSOs (Transmission System Operators), which operate electrical transmission grids and are in charge of the permanent balance between production and consumption on the grids. They are the only buyers for grid services which are provided by electrical producers and loads. They should be aware of all the potential providers and possibly adjust the market mechanisms accordingly, to open the markets to relevant new participants.

- Depending on the future evolutions of grid services market design, DSOs are also likely to be interested in having a comprehensive view of the potential grid services providers to adjust the design of possible new grid services accordingly.

- For policy makers who are in charge of grid services market supervision, as some of the current barriers observed nowadays are related to regulatory framework.

- For energy portfolio managers and aggregators who may integrate WE in their portfolios and who are thus interested in understanding how WEs could improve the techno-economic performance of their portfolio.

- For WE manufacturers and future WE operators; participating in grid services can be a potential complementary revenue that could contribute to improve business cases profitability. That is important for solutions which are still at the early stage of their deployment.

- For technology developers who are interested in developing hybrid solutions, such as Wind/WE and PV/WE, that can directly convert intermittent renewables into reliable green hydrogen.

- For the international hydrogen standardization community (ISO/IEC), which are interested in transferring the test protocols to an international standard deliverable. This will ensure keeping the project findings alive for further uptake by a broad group of stakeholders.

3 Key outcomes of the economic analysis and associated recommendations

3.1 Summary of the work

An economic analysis has been conducted in WP6. The WP was divided into five tasks, and the present report is associated to the last task of the WP (T6.5).

First task of the WP (T6.1) focused on identifying the countries that are offering today the best potential for positive business cases for WE producing hydrogen and offering services to the grid (key criteria were cheap electricity prices, grid services offering interesting remuneration and potentially significant markets for green hydrogen). A comprehensive grid services survey at the transmission and distribution level in Europe has notably been conducted in the scope of this task.

Second task of the WP (T6.2) defined these possible business cases in more details, especially what the market for the hydrogen produced could be. First calculations and economic analyses were conducted on selected business cases. On the distribution level, an exemplary case of congestion management through wind curtailment was considered as no grid services markets exist and therefore no data. Discussions between the partners in the scope of T6.1 & T6.2 also highlighted an interest in considering prospective evolutions to complete the picture given by the analysis.

T6.4 studied in more details 4 specific business cases. Detailed description of the business cases and of the technical and economic assumptions was initiated in T6.3 and refined in T6.4. Economic assumptions for WE took into account FCH-JU KPI targets.

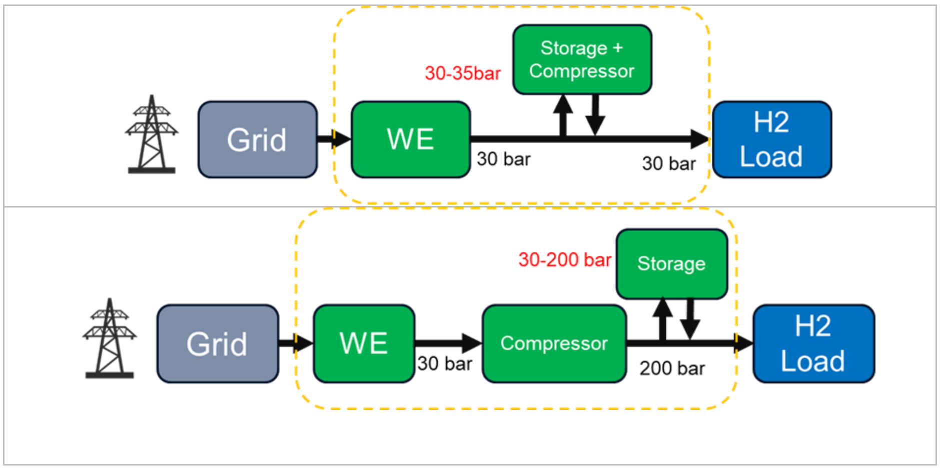

Figure 1 – Business cases studied in today's situation

The first two business cases were located in Germany and studied in today's context. The opportunity to participate in 2 different grid services (FCR & aFRR) has been studied for both business cases. The results have confirmed that participation in grid services could improve the economic performance of the system. In today's situation in Germany aFRR has appeared as the most interesting grid service. Different participation strategies have been identified. A testing experience in real bidding conditions would be needed to assess more precisely the optimal participation strategy and the exact value for the WE that could come from the participation in the service.

The two other business cases were studied in a prospective context. This has required to identify the potential evolutions that could impact the system: improvement of WE efficiency, reduction of WE costs, increase of the share of intermittent Renewable Energy Sources (RES) in the electrical production mix conducting to a different structure of electricity prices… A lot of uncertainties around the evolution of grid services market have been identified, both in terms of market size and market prices: new constraints coming from RES could increase the need for flexibility, but the number of competitors on the market is likely to increase.

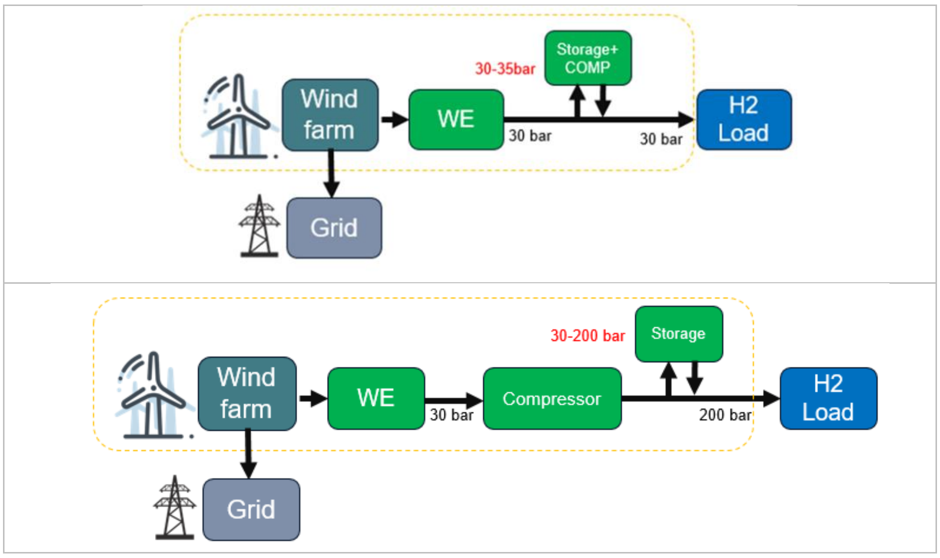

Figure 2 – Alternate configuration studied for prospective business cases

A different configuration has been studied for these two prospective business cases, aiming at extending the first investigations conducted in T6.2 on wind curtailment. We considered a WE directly powered by a wind farm. Several advantages in favour of this kind of architecture have been identified including a potential interest from the grid point of view: it could alleviate the constraints created by the wind farm on the grid and reduce the need for grid reinforcement by reducing the power level that would transit on the grid. The WE may also use electricity that may have been curtailed otherwise, avoiding electricity losses
Though there are too many uncertainties on the future evolutions to evaluate the exact value that could be retrieved from these potential benefits. These points would need to be investigated notably with the help of TSOs.

One has to note that in all the cases, WE are providing grid services just by adjusting their power consumption level. We did not consider in the scope of QualyGridS project systems combining WE and Fuel Cells (FC). Such Power-to-Power applications are envisioned as possible solutions for the seasonal flexibility need of electrical grids, not for grid services market (which is used to serve the instantaneous flexibility need of electrical grids).

More details on the project's results on economic analysis can be found in the project's publications listed in the References section at the end of the report.

3.2 Main outcomes of the analysis and associated recommendations

The main findings of the economic analysis can be summarized as follows:

Findings	Associated recommendations
In today situation, some grid services cannot be provided by flexible loads.	Communicate towards TSOs, DSOs and policy makers on the technical ability of WE; disseminate as much as possible positive test results.
A lot of grid services require a minimum power to participate.	Bigger WE size will ease grid service participation.
There is a real complexity around grid services linked to the differences in the mechanisms from one country to another: some products are symmetrical in one country, asymmetrical in others, the bidding processes are different, and all these differences have an impact on the economic opportunities for WE. There is also a lack of consistency on the data that can be found; ENTSO-E transparency platform has notably inconsistent data that only active data quality management can fix.	1. Support the on-going harmonization effort from the TSOs. 2. Develop a database designed in the first place for WE manufacturers and operators : a. Based on the grid services catalogue established in WP6, this database would include up-to-date information on grid services characteristics (including all the details around bidding process, commitment period, average remuneration over the past year…) b. This database could also include a repository for all the economic analyses performed on flexible loads providing grid services in European countries c. It could also include experimental results from demonstration projects (more and more demonstration projects involving WE include testing of grid services participation).
There is a potential interest for WE in participating in grid services; the potential gain will not justify by itself the installation of a WE, but it can improve the economic performance of the system.	Disseminate the results towards WE operators and manufacturers to generate their interest and raise awareness on the topic.
Some grid service characteristics reduce the economic opportunity for WE (for instance, in today's situation, symmetric grid services products are likely to be less interesting for WE compared to asymmetric products)	1. Support TSO effort to develop more “flexible” grid services products (asymmetric products, more frequent bids, shorter commitment period…). 2. For symmetric grid services, investigate the technical feasibility for WEs to operate over nominal power for a short amount of time.
The analysis performed in the scope of QualyGridS project helped to get a deeper understanding of grid services mechanisms; it identified which grid service could	Conduct on experimental simulation in real market conditions and/or try to gather as much information on relevant testing conducted for instance in demonstration

Findings	Associated recommendations
bring the highest benefit in Germany. Though this analysis has some limits. The calculations were done on historical data assuming a perfect knowledge of all prices on the whole year. There is an important uncertainty on the gain one can really get from grid services.	projects; note that this simulation does not necessarily imply using a real WE system, but simulate it in the portfolio of an aggregator, to access the real electricity prices and the real performances in the bidding process. If possible, this simulation would be conducted / data would be gathered in different countries. These demonstrations are needed to definitely convince WE operators and WE manufacturers of the interest of participating in grid services.
The analysis also highlighted other key elements not directly linked to grid services, which are commonly shared in economic analyses of business cases involving WE, notably the weight of the fixed costs (CAPEX and fixed OPEX) and the weight of electricity prices (price level including taxes and grid fees, price distribution over the year) on the economic performance of the WE.	1. Support the development of regulatory framework for electricity prices adapted to WE, for instance, EEG surcharge exemption for WE in Germany (that corresponds to the assumption taken in our analysis). 2. Support R&D effort to reduce WE CAPEX reduction
Special applications with potential interest (though small market share) like island grid stabilisation, DSO congestion management were not really studied because no general market data available.	Analysis of these applications should be conducted on real cases.
Study of potential prospective evolutions highlighted WE could provide flexibility to the electrical grid not only through grid services. Low or very low electricity prices will be one of the signals for flexibility need. CAPEX of WE are likely to strongly decrease in the long term. With both effects combined, the optimal number of operating hours of the WE might decrease; the optimal participation strategy in grid services might also be modified.	In the future the WE might have to frequently alternate from stand-by mode to operating mode if they want to avoid high electricity prices. Stand-by mode with low power consumption and quick start would then be an advantage. WE manufacturers and operators have to monitor these possible evolutions.
A direct connection between a WE and a wind farm might be an interesting configuration. The benefit it could bring to the electrical grid needs to be assessed.	Study the interest of the alternate configuration in future R&D projects : ➢ Study the technical feasibility for a WE to be directly connected to a wind farm ➢ Simulate the added value it could bring to the grid with appropriate software

4 Key learnings on the technical aspects and associated recommendations

4.1 Summary of the work & overview of the main testing results

The goal of this work was to establish a single test protocol that could cover all the requirements to participate in grid services from the different European countries. Successfully running the test protocol would be a guarantee for WE operator that the WE will be able to pass the prequalification procedures and participate in grid services whatever the European country considered.

The work started with collecting the technical requirements of electricity grid services and the technical abilities of WE. It turned out already at this stage that many services were not clearly defined and that there was a lack in information publically available.
For most of the better defined services there are typical power profiles in real grid service operation, specific requirements like the maximum time a grid service must be maintained on the one hand and prequalification procedures on the other hand. However prequalification procedures and requirements are quite variable between the countries.
Finally we tried to combine the prequalification procedures and typical operational profiles with the most restrictive and challenging requirements to make sure that WEs qualified in these protocols would be available for the respective grid service in all countries. What turned out to be a challenge was not only to find the technical information at one time but also to update with serious changes occurring during the project's duration due to incentives from the European Commission to further harmonize grid services design.

Some services and markets that are differing a lot from the rest, like the UK, could not be addressed in detail. However by determining parameters of WE systems based on tests as relevant for TSO services and combining with some basic characteristics of the system will help also for services not considered here to decide on the technical readiness of the WE.

From the initial technical survey of WEs and the general believe in the community it was expected that PEM WEs would be more easily performing the faster grid services than alkaline WEs.

Three alkaline WE systems and two PEM WE systems were tested with the testing protocols in two stages of draft. All systems were state of the art stacks and systems, however most of them were not technical size systems but relatively small systems, downscaled technical systems in test benches. Some minor adaptations to the systems were made, e.g. in the control, data acquisition or BOP system components.

The purpose of the testing was to evaluate the applicability of the testing protocols and if the goal to decide on readiness for grid service can be achieved. Another goal was to check if the systems tested were ready for grid service applications or what gaps still required further development.

As it turned out that the size and exact configuration of the BOP system has a serious influence on the grid service ability further analysis was made of a 1MW PEM WE system's data that has performed similar tests to the ones required here in the scope of another project.

Feedback from the tests helped to improve the testing protocols. Those are at the end of the project ready to be internationally worked out as an ISO technical report and were also provided to the JRC's activity for providing harmonised testing protocols for WEs.

Some Key Performance Indicators (KPI) were defined from this work and relevant target values for these KPIs are suggested together with the description how to determine these KPIs from the tests.

The tests conducted in the scope of QualyGridS project gave positive signals on the capability of WE to provide grid services. It notably highlighted that although flexibility is often more associated to PEM WE, advanced Alkaline WE have the same flexibility in terms of ramping and load following ability ; alkaline WE systems that were built with the purpose of good dynamics and flexibility could do the ramping as required by the tests. The difficulties to participate in grid services that have been identified do not come from the chemistry, but from the BOP, the power electronics and the control that must be conceived the right way for dynamic operation.

Thus some issues observed during the project came from the power stability required by the tests: the smaller systems had comparably high fluctuations of the BOP system power; running the grid services profiles in an appropriate way was possible with the stack respectively the rectifier input power however not for the total system power. Based on the experience of the manufacturers in the project this should not be a problem because frequently only the rectifier input is connected to the high voltage grid and can therefore be used for TSO services while the BOP is connected to lower voltage grid. However, in cases where grid connection costs for two separate connections might be high, it would be desirable to have the grid service provided by the total WE system.

It could be seen for the systems analysed in the project that for higher system power the relative BOP power consumption was much smaller therefore giving better efficiency and more power stability. However the smaller systems in the project were intendedly not small, efficiency optimised systems but down-scales larger systems and were associated with hardware appropriate for larger systems. This was done to get a similar performance on these smaller systems as on large WE. It was hoped that determination of WEs' properties could be done on smaller, less CAPEX- and OPEX-costly systems. However it turned out that the BOP configuration as well as the stack size have a serious impact on the grid-relevant parameters of WEs so that it is very difficult from the behaviour of small systems to extrapolate the behaviour of large systems.

More details on the project's technical results can be found in the project's publications listed in the References section at the end of the report.

4.2 Main recommendations linked to these results

Findings	Associated recommendations
About WE design for grid services:	
The testing protocols have defined tests and KPIs of the system determined from these.	As a general requirement for WE providing grid services, WE must be able to react to power changes as fast as it is required depending on grid services (FCR, FRR, etc), respecting the tolerances and grid constraints defined by each grid operator.

Findings	Associated recommendations
	This is the most important goal of performing the pre-characterisations and defines the system development line.
After analysing the technical requirements for grid services, it was not possible in this project to include all technical requirements of all countries.	As requirements are varying from country to country there should be a database and an always updated overview of the technical documents. Information provided in the database should also include specific technical requirements like e.g. the required tools to fulfil with the communication protocols and measurement requirements defined by each grid operator. One also has to be aware that no matter if the WE performs grid services or not it has to fulfil the countries' requirements e.g. in network disturbances, connections, tests required that could also be provided in the database. In the future more harmonisation in Europe would be desirable.
All WE in the project apart from one outside the project that was also evaluated were originally current-controlled. Using current control without further tries to implement power control was to some extent possible; however after one system was equipped with power control it could follow the requirements much better.	WE should be power-controlled. This requires the implementation of a control strategy; if the stack current is still the controlled parameter, the control should be based on the requested system power level and not the requested amount of hydrogen. Using a rectifier which is based on power control could further improve the results.
Several of the systems were fed with the data set points by script lists processed internally. One system had serious problems implementing a way to give input of the required parameters. By the internal script lists often the desired power vs. time request to the system could not be implemented precisely.	Considering the real grid service application the system should have in the test an interface to an external set point input with the test bench set up in such a way that an external trigger with verified power level vs time request signal should give input to the system via this port simulating either the output of a grid frequency measuring device for FCR or the automated TSO's power request signal.
All WEs initially had a data acquisition/control rate of 1 Hz or lower. This caused problems with properly implementing the FCR power requests.	For FCR and potential future faster control services a faster data acquisition is recommended. Typical operation parameters (pressure, gas purity, temperature…) could remain with 1 Hz or lower data acquisition rate but those related to power (and current, voltage) requires to have a

Findings	Associated recommendations
	faster acquisition rate. It is not needed to have all parameters collected with such demanding data acquisition rate as files obtained are harder to be processed.
It turned out in the project that prediction of the grid service behaviour of a large system is hardly possible when testing a down-scaled system. However for cost reason this would be desirable.	A simulation tool would be needed that can, after performing a set of measurements with the down-scaled system predict the behaviour of the real size system.
Degradation rate changes due to grid service operation could only partly be considered in this project. Higher degradation rates may be caused by maximum power operation, frequent switching between low and high power. Quick ramping up from low power (lower system temperature) to high power is also expected to cause degradation.	Further experimental studies on these degradation effects and the development of Accelerated Stress tests accelerating specifically one mechanism is needed.
With the systems tested in the project achieving the required power stability with the total system power including all BOP components was impossible for most (but not for all). For these small-scale systems, there was not an optimised BOP setup.	Low BOP power consumption is a goal for WEs because it increases the efficiency. It is mostly a challenge today for small size systems; it is already the case for large systems. Smoothly power-controllable BOP system would be a nice-to-have feature to allow grid service not only for rectifier input but for full system.
More general notes about WE:	
A lot of applications require pressurized hydrogen. The pressure storage analysed in the economic analyses had a minimum of 30 bar pressure	As the applications need a pressure storage to decouple power consumption profile and hydrogen delivery profile, increase of pressure level of WE compatible to storage without compressor may be useful (provided it does not increase the CAPEX too much). Operating pressure influences the available power range of the WE as it influences the gas purity obtained; it will cause that the minimum power needs to be higher; an optimum will thus have to be found depending on the application.
Today every WE is specially designed for the application.	For cost reduction in future more standardisation would be needed.
Influence of environmental conditions on performance level (power stability/controllability) was only partly studied in the	This influence should be considered in system design and needs further studies as well as testing equipment that measures e.g. heat transfer in/out of the

Findings	Associated recommendations
scope of the project. One observation was the influence of high ambient temperature.	system and simulation software that considers the cases that cannot be experimentally verified. This affects more small systems/stacks as the thermal inertia is lower that bigger systems/stacks
Impact of the hydrogen use case on the WE operational profile was not experimentally studied in the scope of this project.	Test grid services participation in several operational setups (WE used Hydrogen Refuelling Station, on an industrial site…).

4.3 Perspectives on additional tests that could be conducted

This section summarizes the tests that could be conducted after this project (possibly in future call for projects coming from FCH-JU or other funding agency if relevant global project frameworks are identified):

- Test the protocol on WE with a good power control at the system level, with a specific focus on the implications of this power control on the stack and the BOP components

- Test the protocol on larger scale (above 1MW) systems involving multiple test sites (with a comparison between system vs. rectifier input power)

- Evaluate system performance in real grid services operation, measuring the realistic power profile of the service and investigating system component's behaviour in this operation, notably:
  - Evaluate gas quality vs time while performing grid services because this influences the possibility to use this hydrogen for different applications and might require to reject hydrogen with some impurities, therefore reducing efficiency.
  - Evaluate system efficiency vs time in grid service operation because the efficiency might differ substantially from the steady-state values that are provided by the manufacturers.

- Evaluate the long term effect of participating in grid services on the performances of the system (does that affect the efficiency of the system in the long run? Does it reduce lifetime? Does it imply more frequent BOP component maintenance and replacement?
  - Develop accelerated stress test to simulate degradation in grid service operation

- Conduct tests on the influence of environmental conditions on performance level (power stability/controllability).

- Conduct an evaluation of test protocols with standby as lower power level.

- Conduct tests to evaluate the possibility to operate overcapacity for a short period of time.

- Consider the option of adding other flexible options (e.g. a small battery, a more powerful rectifier allowing for fast power regulation) into a WE system, and compare this with the current solution, i.e. using WE alone to provide grid services (including a techno-economic performance assessment).

5 Recommendations for the dissemination and standardization of the test protocol

5.1 Short-term dissemination of the test protocol

The test protocol is ready to be used, and the goal is to have it used as much as possible. It will be available from October 2020 at the following address: https://doi.org/10.5281/zenodo.3937273

QualyGridS partners have already been working actively on presenting the test protocol (for instance during the final online project workshop or during international conferences such as International Grid Service Markets Symposium in Lucerne, Hypothesis online conference…). A scientific publication describing in details the protocol is also in preparation.

In the coming months, demonstration projects appear to be the most relevant framework to have the test protocol used.
We recommend that FCH-JU disseminates the test protocol towards all its demonstration projects involving large-scale WEs and encourages its use.
All QualyGridS partners can also contribute to disseminate the test protocols in the demonstration projects where they will be involved in the future.

Positive feedbacks regarding the use of test protocol (easy to understand and apply…) and its relevance (WE passing all the tests successfully then able to pass pre-qualification procedures and participate in grid services in a given country) will be a key success factor.

Feedbacks from TSO on the test protocol (still missing as of today) would also have an important added value. It will maybe be possible to reach them through the demonstration projects.

A survey about the learnings from all these demonstration projects (using test protocol or testing grid service participation would also be very valuable and could enrich the suggested database (but might be limited by confidentiality issues).

To conclude this part about short-term dissemination, one has to note that QualyGrids test protocol has also been shared with JRC to contribute to their on-going effort of standardization of WE testing activities.

5.2 Standardization of the test protocol

An important aim of the project was also for the purpose of broader dissemination to have testing protocols fed into the international standard development process. On a global level, the most relevant technical committees are ISO/TC 197 “Hydrogen technologies” and IEC/TC 105 “Fuel cell technologies”. Both committees have been approached and continuously informed about the testing protocols, among others by multiple presentations. Following a recommendation during project final workshop, collaboration with

IEC/TC 8 “System aspects of electrical energy supply” & IEC/TC 120 “Electrical Energy Storage Systems” will also be established if possible.
Following a presentation by the project on the standardized testing protocol, the resolution below has been taken at the ISO/TC 197 Plenary in December 2019 in Grenoble:

> *TC197 welcomes the proposal of NEN of a NWIP on testing protocols for WEs performing grid services in collaboration with IEC TC105 and IEC TC 8. NEN is invited to submit the NWIP within 3 months. ISO TC197 will take the lead*

It has been recommended by ISO/TC 197 leadership to develop a technical report on the testing protocols. This technical report paves the way towards a full international standard. The New Work Item Proposal (NWIP) has been submitted to and approved by the technical advisory board of ISO/TC 197. Key project partners (DLR, CEA) will take the lead and stay technically involved with the further development of the ISO deliverable. The test protocol has been formally submitted to ISO/TC 197 and a committee internal ballot for project approval among ISO/TC 197 members will be launched in July. This will safeguard lasting impact and exploitation of the project through the implementation of the testing protocols. The technical report will take into account all the feedbacks coming from upcoming users of the test protocol.

5.3 Long-term dissemination of the test protocol

Once the test protocol will be turned into a standard, one can imagine to have a certification associated with a successful run of the protocol. The idea of this certification has been positively welcomed by WE manufacturers involved in the project, notably because it would make comparison between technologies easier.

6 Summary of the recommendations and implementation plan

6.1 Summary of the recommendations

- Some key technical points were identified to ease WE participation in grid services (notably WE should be power-controlled); these findings will be useful for WEs manufacturers in the future.

- Positive outputs came out from the project (both on the capability of WEs to provide grid services and on the potential economic impact of grid services participation); they should continue to be disseminated.

- Harmonization of grid services and larger market opening effort from TSOs, DSOs and policy makers should be supported by WE & hydrogen technologies community ; this suggestion could be expressed for instance in the Hydrogen Development Plans that are under development in different countries (Germany, France…).

- Meanwhile, establishment of a database dedicated to WEs manufacturers & operators including technical data (pre-qualification procedures…) & economic data on grid services market would be very useful.

- Dissemination of the test protocols should be continued; in the short-term, it would be particularly relevant to test them in demonstration projects involving large-scale WEs (>1MW).

- A list of additional tests to conduct has been identified by QualyGridS partners; it would be interesting to include these tests in future projects.

6.2 Implementation plan

2020-2025

- Test protocols to be used in demonstration projects especially on large systems ;
- Establishment of the grid services database for WE operators & manufacturers ;
- Standardization effort for the test protocols to be continued (towards ISO standard); dissemination of the newly-established standard ;
- Additional technical investigations (on degradation…) to be conducted.

2025 -2030

- Following positive results in demonstration projects, WEs in commercial projects are commonly offering grid services;
- ISO standard is recognized by the community and updated on regular basis;
- A related certification is created;
- The grid services database continues being updated.

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