Development of a Proposed Performance Standard for Battery Storage System connected to a Domestic/ Small Commercial Solar PV system

Final Project Report

Project Partners

DNV·GL

CSIRO

SMART ENERGY COUNCIL
SOLAR, STORAGE, SMART ENERGY

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Table of contents

List of tables

List of figures

1 INTRODUCTION

1.1 The current situation

Australia has one of the highest proportions of households with PV solar systems in the world. With record high retail electricity prices (in 2019), comparatively low feed-in rates for exported PV energy and market competitive energy storage costs, the market for behind-the-meter battery systems has the potential to increase dramatically.

The two critical aspects of battery systems are safety and performance. As of 2019, Standards Australia has released 'AS/NZS 5139 - Electrical Installations - Safety of battery systems for use with power conversion equipment' [1] that mainly addresses the installation and safety aspects of battery storage equipment (BSE).

However, with respect to performance, there is no existing standard and presently limited information available to allow consumers to make an informed choice regarding the performance of BSE.

Currently, battery performance is determined by manufacturers, each utilising their own methods. Since the performance values are dependent on the measurement methodology, even simple metrics such as capacity, power output, and cycle life are not comparable between manufacturers. Further, the measurement methods currently employed typically are not reflective of how the BSE is used in the anticipated application. This can lead to situations where consumers believe that the systems are suitable for their intended application and then find performance and lifetime are well below expectations. A potential widespread loss of consumer confidence presents a critical risk for establishing a long-term, self-sustaining viable industry. The lack of ability to make an informed choice also represents a major barrier to entry for battery storage equipment and may restrict the adoption of this technology, which in turn will limit the effect of this important enabler of increased renewable energy penetration on the grid.

1.2 The approach

A Project Consortium consisting of DNV GL, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Smart Energy Council (SEC) and Deakin University was established to develop a proposed performance Standard for battery storage equipment (BSE - alternatively known as battery energy storage equipment) connected to residential and small-scale commercial solar photovoltaic (PV) systems. This proposed performance Standard is currently referred to as the Australian Battery Performance Standard (ABPS).

This Project received funding from the Australian Renewable Energy Agency (ARENA) through its Advancing Renewables Program and the Victorian Government through its New Energy Jobs Fund. In executing the Project, a project Steering Committee was established to manage the Project effectively, as well as an external Stakeholder Reference Group (SRG). The SRG consisted of representatives from battery manufacturers, industry associations, government agencies and end-users, and was established to guide the progress of the ABPS Project. Additional stakeholder engagement and advice, beyond that of the SRG, was also sought.

The Project had a 2-year timeframe and was launched in July 2018. It consisted of two key stages for the development of the ABPS as listed here:

Stage 1:

- ✓ Undertake a gap analysis of existing local and international standards, codes, best practices and guidelines related to testing and reporting the performance of battery energy storage systems
- ✓ Analysis of the battery performance data generated by ITP Renewables under a separate ARENA funded Project[1]

Stage 2:

- ✓ Development of performance metrics and test protocols
- ✓ Battery performance testing
- ✓ Creation of draft Standard and Industry Best Practice Guide
- ✓ Development of a battery capacity estimation methodology
- ✓ Development of recommended criteria to select a battery management system (BMS)
- ✓ Development of a process to identify performance related hazards
- ✓ Recommend minimum set of information for safety data sheets (SDS)

1.3 The main scope and objective of the Project

Although there were several activities undertaken as part of the Project, the main scope and objective were to develop a draft Standard (i.e. the ABPS) and Industry Best Practice Guide. These documents provide standardised testing and reporting requirements for the performance of BSE designed to be used within residential or small-scale commercial applications in conjunction with solar PV systems.

The documents define the following as they relate to BSE performance:

- Performance indicators/metrics
- Standardised testing protocols for performance metrics
- Standardised reporting requirements for performance metrics

The documents are applicable to the following types of BSE:

1. Using secondary or rechargeable cells
2. With a nominal power equal to, or less than 100 kW
3. With a rated capacity equal to or greater than 1 kWh and no more than 200 kWh at the 0.2C rate.

While this does not apply to systems with nominal power greater than 100 kW or capacity greater than 200 kWh, the principles therein can be applied to these systems in the absence of specific standards.

Under the Project, the APBS has been developed and was submitted to Standards Australia on the 21st of May 2020 for consideration as an Australian Standard via its standard development process. During the period that the Standards Australia process is underway, interested industry stakeholders may choose to apply a similar approach, as described in the Industry Best Practice Guide.

[1] "Testing the Performance of Lithium Ion Batteries". Project information available at https://arena.gov.au/projects/testing-the-performance-of-lithium-ion-batteries/

1.4 Applicability

Manufacturer's, regulatory authorities, testing laboratories, certifiers, importers and others can use the principles in these documents as a consistent standard against which they can assess whether the performance of BSE is suitable for Australian household and small-scale-commercial environments.

End users of BSE will be the greatest beneficiaries of the APBS and Industry Best Practice Guide. This allows them to make informed choices regarding the performance of different BSE available in the market, in view of their intended applications. End users would be able to recognise through product datasheets that the products they are comparing have been tested and reported according to standardised methodologies.

Other parties in the battery supply/purchase chain, including cell manufacturers, module/pack manufacturers and battery system manufacturers, may also benefit. Manufacturers and system integrators can use the recommended test methods and associated reporting requirements to demonstrate that their BSE is suitable for Australian conditions.

1.5 The project structure

As noted in Figure 1, in addition to the Project Consortium (i.e. DNV GL, CSIRO, Smart Energy Council, Deakin University) and funding agencies, the Project involved many other external parties. Those included the SRG (refer to Section 1.7 for more information), DNV GL battery testing center (i.e. NY BEST), Standards Australia, ITP Renewables and Pacific Northwest National Laboratory (PNNL)[2]. The high-level role of each party is listed in Table 1.

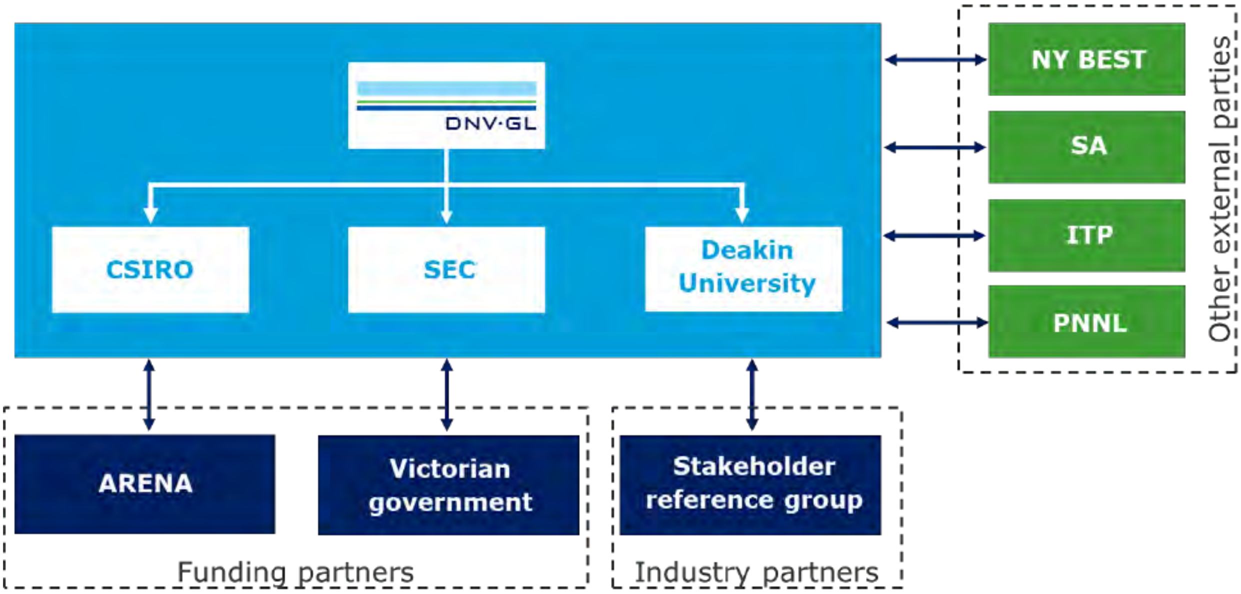

Figure 1: Project Governance Structure

Table 1: Role classification

Activity	Role Description	Website
DNV GL	Project Lead	https://www.dnvgl.com/index.html

[2] One of the United States Department of Energy national laboratories, managed by the Department of Energy's Office of Science

Activity	Role Description	Website
CSIRO	Project Consortium member	https://www.csiro.au/
Smart Energy Council	Project Consortium member	https://www.smartenergy.org.au/
Deakin University	Project Consortium member	www.deakin.edu.au/
ARENA	Funding agency	arena.gov.au
Victorian Government (DELWP)	Funding agency	www.delwp.vic.gov.au
NY BEST DNV GL entity. Battery and Energy Storage Test center (BEST). Located at Rochester, New York, USA.	Informal knowledge sharing partner. The Project Consortium received informative feedback from NY BEST on the battery selection and performance metrics development activities.	https://www.ny-best.org/
Standards Australia (SA)	Stakeholder Reference Group (SRG) member and the recipient of the ABPS.	www.standards.org.au
ITP Renewables	Stakeholder Reference Group (SRG) member and data sharing partner.	https://itpau.com.au/
Pacific Northwest National Laboratory (PNNL)	Informal knowledge sharing partner. The Project Consortium contacted PNNL in the early stages of the Project to understand its scope of work in relation to measuring the performance of battery storage systems. In addition, the Project Consortium received valuable feedback from PNNL on the ABPS.	www.pnnl.gov
Stakeholder Reference Group	For more information refer to Section 1.7	

1.6 Project timeline

The Project concept was identified in late 2016. This was verified via a thorough literature review and series of industry consultations. The Project was officially started in June 2018 and then progressed through the five main milestones and two interim milestones culminating in mid-June 2020, with each main milestone having approximately six months[3] duration. Figure 1 shows the due date of each of the milestone deliverables.

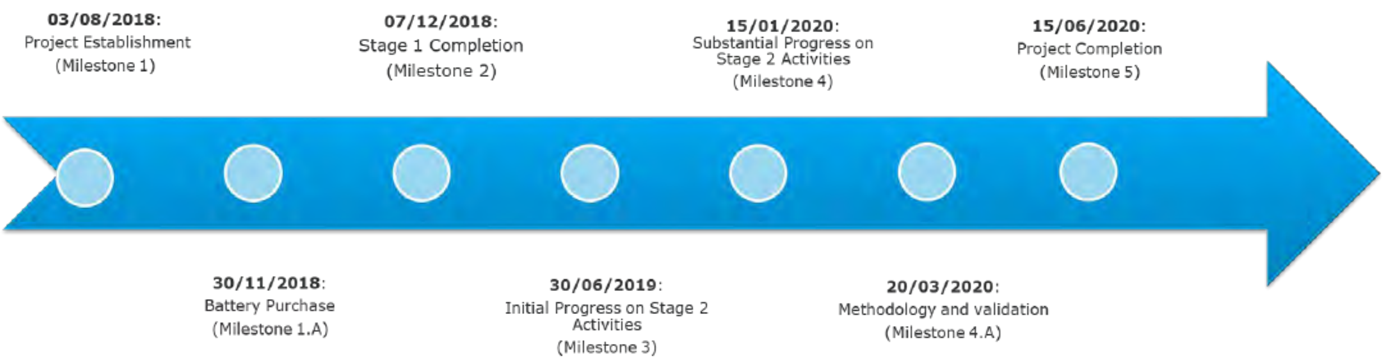

Figure 2: Project Timeline

1.7 Stakeholder Reference Group (the SRG)

A stakeholder reference group was established for the Project to ensure broad stakeholder consultation and feedback on the delivery and development of the Project. The SRG consisted of a broad range of key stakeholders relevant to the development of the ABPS.

The SRG helped to ensure that the Project received extensive feedback from stakeholders on the key project activities, which was one of the key elements for the development of the ABPS. The number of stakeholders grew throughout the Project and stakeholder engagement increased as the ABPS and Industry Best Practice Guide was developed. A list of the industries / organisations covered by the SRG is shown in Table 2.

[3] However, based on the contract variations, some project milestones were amended

Table 2: SRG member industries

Industry
Battery manufacturers
Smart energy software
Consumer bodies
Energy distribution
Energy retailers
Engineering consulting
Generator, retailers
Government agencies
Industry associations
Inverter manufacturers
Power systems
Regulators
Renewable energy consultants
Research institutions
Standards body
Training providers

2 IMPORTANCE OF AN ABPS AND INDUSTRY BEST PRACTICE GUIDE

The main performance metrics of BSE connected to solar PV applications are not expressed uniformly due to the lack of a common standard approach to defining and measuring them. The current industry practice is for manufacturers to define and measure performance metrics (e.g. maximum power, energy, efficiency, capacity, etc.) following their own protocols which are independent of others, and not always disclosed. Additionally, the reported performance often is not reflective of real-world performance in the application for which the battery is used. Therefore, the available information on these battery systems is not uniform and does not allow for a direct comparison between the products of different manufacturers. Ultimately, this leads to confusion within the industry and, most importantly, for end-users. Furthermore, the advertised performance metrics of some batteries may not be attainable in real world conditions, and result in performance that is not in line with expectations.

The ABPS and Industry Best Practice Guide developed as part of this Project can be used to ensure that the large-scale rollout of solar PV-battery schemes can proceed throughout Australia on the basis of consistent expectations, thereby minimising the risk of a perceived or actual underperformance or failures, and hence supporting consumer confidence in products. By clearly and explicitly defining what is to be tested, how it is to be tested, and how it is to be reported, it will allow potential end users of BSE to fairly compare performance metrics between various manufacturers. Furthermore, the standardised testing and reporting will be for Australian specific conditions, which will provide realistic expectations around the performance of the BSE under real world conditions in Australia.

It is understood that the rapid uptake of BSE is, in part, impeded by the lack of a regulatory framework around this technology. If the ABPS is implemented as an Australian Standard, it will act as a barrier for unknown and potentially underperforming assets entering into Australia. The ABPS will also greatly enhance the confidence of small to large investors and grid operators in the technology, thus leveraging the investment opportunities in the battery storage market.

3 THE PROJECT OUTCOMES

This section outlines the project reports that were prepared and associated activities that were undertaken to complete those reports. The reports are publicly available via the Project Consortium knowledge sharing websites and will also be made available on the ARENA Knowledge Bank:

- DNV GL: www.dnvgl.com/ABPS
- CSIRO: research.csiro.au/abps/

As outlined in the introduction, the entire Project was divided into two stages and then structured to progress via five milestones (Stage 1: milestones 1 – 2; Stage 2: milestones 3 – 5). The Stage 1 activities were completed within the first six months of the Project. The outputs of the stage one activities were used to inform the detailed activities to be undertaken in Stage 2. The following subsections describe the main project outcomes/activities that were undertaken throughout the project life span. The majority of those project outcomes formed the basis for the knowledge sharing deliverables described in APPENDIX II – COMMUNICATION AND KNOWLEDGE SHARING ACTIVITIES.

3.1 Stage 1: Standards and data analysis

A gap analysis of existing standards was considered as the major activity under stage 1, which was used to determine the degree to which any existing standards could be adopted or adapted for use in Australia. In addition to this, other activities were undertaken, which were useful in designing stage 2 activities. The main stage 1 activities were:

- A comprehensive gap analysis on existing local and international battery energy storage performance standards
- A review and analysis of data and outputs from the related ARENA-funded ITP Renewables project "Testing the performance of lithium-ion batteries" [1]
- The development of a proposed high-level Standard (using the template provided on the Standards Australia website)

More detail on the first two activities is provided in the following sections.

3.1.1 Energy storage standards gap analysis

The Project Consortium [4] undertook a comprehensive review and gap analysis of existing local and international battery energy storage system related performance Standards, best practice documents, guidelines and codes, to achieve the following outcomes:

1. Understand and communicate the current framework and coverage of existing documents
2. Avoid reproduction of work already completed by others
3. Identify areas where efforts are needed and should be focused to maximise value for the development of the ABPS

To begin this gap analysis, the Project Consortium initially compiled a list of approximately 258 documents for review. This was subsequently, through broad consultation, reduced to a list of 124 relevant documents for detailed review. Documents were drawn from various local and global Standards organisations such as the Institute of Electrical and Electronic Engineers (IEEE), International Electrotechnical Commission (IEC)

[4] The review work was undertaken by CSIRO and DNV GL's team members across Australia, Europe and the USA.

Underwriters Laboratories (UL), Australian Standards etc. Each document was reviewed using a proforma template that was developed for the task, to assess relevancy and adequacy concerning the scope of the ABPS. Standards were reviewed against a pre-determined set of performance categories and additional review items. This was to ensure consistency of reviews and enable comparison and consolidation of results, in preparation for Stage 2 of the Project, leading to the development of the ABPS.

The Project Consortium found that based on this comprehensive review, no international or local Standard was found which could be directly utilised in the Australian market to fulfil the defined scope of the Project. Several gaps were identified in the existing Standards coverage, which was addressed during the ABPS development process.

However, a limited number of Standards were identified to have major relevance to the ABPS scope and intent. In addition, a significant number of Standards were found to contain information that was considered to be useful for the ABPS. For example, some definitions, formats, performance metrics and measurement parameter tolerance levels presented in other standards were utilised when preparing the ABPS and Industry Best Practice Guide.

The Project Consortium prepared three versions of the gap analysis;

(a) one for the Project funding agencies as a confidential document[5] , which consisted of all the summary tables of each reviewed Standard as an appendix to the main document.

(b) The same as the document (a) without appendices, that can be used as a comprehensive guide by any interested parties [2]

(c) A summary version of (b) which mainly consists of the high-level findings [3]

The standards gap analysis was undertaken to understand the degree to which any other existing standards from other jurisdictions could be adopted or adapted for use in Australia. Additionally, this piece of work provided justification to the industry as to why this Project was developed. The gap analysis work was highly valuable during milestone 5, especially during one-to-one based industry consultations. Some industry stakeholders questioned whether there are any other similar standards, codes or best practices existing elsewhere.

Once the Project Consortium presented the gap analysis work to industry stakeholders, they acknowledged the importance of the Project and noticed the lack of such work in the coverage of the current standards. The Project Consortium believes that in the absence of the gap analysis work that was undertaken, it would have been difficult, perhaps impossible, to progress the standard development process with Standards Australia.

3.1.2 ITP Renewables data review and analysis

Previous to this Project, ITP Renewables had received funding from ARENA to undertake battery test trials. Noting the synergies existing between this Project and the trials undertaken by ITP Renewables, it was proposed to utilise the ITP Renewables battery test trials data as an informative tool for stage 2 activities of this Project. In this regard, DNV GL and ITP Renewables executed a Memorandum of Understanding. Upon the receipt of the ITP Renewables data, Deakin University was assigned to complete a detailed analysis.

In this analysis, data from a number of batteries with different chemistries installed during phase 1 and phase 2 of the ITP Renewables trials were investigated. The battery chemistries comprised of lithium-ion batteries (namely Nickel Manganese Cobalt and Lithium Iron Phosphate), Advanced Lead Acid, and Lead Acid batteries.

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[5] Noting the copyright issues associated with the reviewed standards

The testing data available covered a period of two years from June 2016 to May 2018, which included information on battery voltage, current, power, and state of charge during charging, as well as discharging conditions for a range of batteries. The purpose of the analysis of the testing data was to compare performance metrics across different battery chemistries and investigate the correlation between the measurable parameters and the state of charge of a battery. These conclusions were used as an informative tool for the development of a generic battery capacity estimation methodology and to draw some early conclusions for the battery testing activities planned at CSIRO testing facilities. A detailed report on the analysis of ITP Renewables data was submitted as part of stage 1 of this Project [4].

The Project Consortium wishes to acknowledge and thank ITP Renewables for sharing the data and its continuous support in the capacity as a member of the Project’s SRG.

3.2 Stage 2: Profile development, testing, ABPS, and Industry Best Practice Guide

The main stage 2 activities of the Project relevant to the ABPS and Industry Best Practice Guide are listed below. Those activities were undertaken during the period of milestone 2 to milestone 5.

- Analyse real-life Australian PV generation and storage data sets and develop a set of test protocols and associated reporting requirements to determine and report the performance of BSE for Australian conditions.
- Demonstrate the appropriateness of the developed test protocols through a series of tests of various BSE chemistries at CSIRO laboratories.
- Draft a proposed Standard and submit to Standards Australia for their consideration and adoption in order to elevate the proposed ABPS to an Australian Standard.
- Produce a guideline/recommended practice based on the proposed ABPS for use by industry stakeholders in the interim whilst the Standards Australia review process is underway.

The following sections describe each of the above-listed activities in further detail.

3.2.1 Develop a set of test protocols and associated reporting requirements

As a part of this activity, the Project Consortium developed several test protocols to determine the performance of BSE with respect to the temperature, solar generation and electrical load profiles to be expected in an Australian context. More specific information relevant to the development of those profiles is listed in Table 3. The profiles formed the basis of the battery test protocols, and their effectiveness was verified at CSIRO's Centre for Hybrid Energy Systems (CHES) in Clayton, Victoria.

Table 3: Temperature and performance evaluation metrics profiles.

Activity	Description
Temperature Profile [5]	The temperature data across 109 weather stations from January 1910 to December 2017[6] was analysed to identify the average Australian temperatures and humidity levels across all states as well as extreme limits. Utilising this information, together with feedback from the industry members, four different thermal evaluation profiles were developed: • Low and high temperature thermal evaluation profile • Extreme temperature thermal evaluation profile • Climate region based temperature performance evaluation profile • Climate region based accelerated aging temperature performance evaluation profile
Performance evaluation metrics and use cases [6]	Evaluation methodologies for a range of different performance metrics were identified as being relevant to solar PV connected batteries. Two use-cases, namely, a residential solar shift profile[7] and a residential solar shift profile incorporating a virtual power plant (VPP) operating mode[8] were determined[9] to be the most appropriate cases to be included in the ABPS and Industry Best Practice Guide. Based on these two use-cases, data analysis of real-life solar PV installations was conducted, and an analysis of Australian electricity markets/state of the art literature review of VPP operating modes was undertaken. Through a detailed analysis of real-life battery usage, a range of different evaluation profiles were developed. The profiles developed were: 1. maximum power test and sustained power test 2. energy, capacity and efficiency test 3. solar energy shift profile 4. solar energy shift profile with VPP operation 5. accelerated solar energy shift profile 6. accelerated solar energy shift profile with VPP operation

[6] Noting that the analysis of the data began in late 2018, data availability was limited to this period of time. Given the temperature range the profiles cover, it is not expected that the recent extreme events will change them.

7 Energy shifting from solar generation to high load demand periods (PV energy time shift). By shifting the load to evening and morning periods, it also acts to reduce demand charging.

8 Energy shifting from solar generation to high load demand periods (PV energy time shift). By shifting the load to evening and morning periods, it also acts to reduce demand charging. In addition, use of grid charging at low energy prices and discharging at high energy prices can be achieved under a VPP operating mode.

[9] This was concluded during workshop #3 at CSIRO on the 9th May 2019. The Project Consortium initially proposed 13 possible use-cases, however, noting the commercial effectiveness and practicality, the industry stakeholders preferred to move forward with two use-cases.

3.2.2 Battery testing

The ABPS testing profiles were supported by experimental evidence showing the validity and the technology-agnostic characteristics of the proposed tests. This evidence-based approach has been used as a verification process to confirm the suitability of the proposed testing methodology described in the ABPS and Industry Best Practice Guide. It was the Project Consortium's view that this approach would enhance confidence amongst the energy storage industry concerning the technical correctness of the proposed ABPS, and thereby assist adoption of the proposed ABPS within Australia without facing major challenges.

In order to achieve this, a range of different battery chemistries was tested to demonstrate the usefulness and applicability of the proposed test protocols. In planning this task, a detailed market analysis of the existing commercial battery storage systems was undertaken. In addition, industry stakeholders' views were also sought. Based on this, a rationale for selecting battery technologies for testing was developed.

After an initial delay in obtaining the Steering Committee acceptance of the proposed battery purchase list, the procurement process was initiated (see Table 4 for an overview of the procured systems). In parallel, the battery testing framework was rigorously improved based on industry consultation[10]. Due to the delay in the procurement process, the start of battery testing was delayed relative to the original plan.

To ensure that the profiles developed were truly technology agnostic, a broad range of BSE were tested. These included cells, batteries and complete systems, in cylindrical, prismatic and pack formats in capacities ranging from approx. 3Wh to 13.5kWh. Testing of the procured battery systems was started in early September 2019 and continued through to the end of May 2020.

A range of different battery testers were utilised for the Project ranging in power from 0.25kW through to 180kW. Additionally, multiple environmental control systems were also utilised for the Project.

Figure 3: Bitrode battery testers

[10] For example, an additional workshop as a result of an ongoing debate on battery testing pathways during Milestone 3.

Figure 4: Small and large climate chambers used for testing

The testing activities were conducted in parallel, where possible, to maximise the number of batteries being investigated. The testing progress was reported to the funding agencies through milestones three to five, in the form of three testing progress reports. The testing has been completed using the different temperature profiles combined with the performance metric evaluation profiles outlined in Table 3, and the final evaluation status is shown in Table 4.

Note that the BSE used for testing of the profiles were anonymised to avoid conclusions being drawn around the performance of particular products.

Table 4: The test matrix - list of batteries being evaluated

Asset No.	Name	Chemistry type	Size	Format	Tests Completed – by Profile number					
					1	2	3	4	5	6
1	LFP01	Lithium iron phosphate	1.2kWh	Battery Pack	C	C	C	C	C	C
2	PBA01	Lead acid	130Ah	Multicell / prismatic	C	C	-	-	C	C
3	NMC01	Nickel manganese cobalt	63Ah	Battery Pack	C	C	C	C	C	C
4	PBA02	Lead acid	100Ah	Multicell / prismatic	C	C	C	C	C	C
5	NMC02	Nickel manganese cobalt	3.6kWh	Battery Pack	C	C	C	C	C	C

Asset No.	Name	Chemistry type	Size	Format	Tests Completed – by Profile number					
					1	2	3	4	5	6
6	LFP02	Lithium iron phosphate	2.56kWh	Battery Pack	C	C	C	C	C	C
7	LTO01	Titanate	1.93kWh	Battery Pack	C	C	C	C	-	-
8	APBA01	Advanced lead acid	1.06kWh	Battery Pack	C	C	C	C	C	C
9	LIC01	Lithium supercapacitor	53Wh	Multicell / prismatic	C	C	-	-	-	-
10	FLW01	Flow battery	10kW	Battery Pack	C	C	-	-	-	-
11	LIC02	Lithium supercapacitor	3.55Wh	Battery Pack	C	C	C	-	-	-
12	APBA02	Advanced lead acid	200Ah	Multicell / prismatic	C	C	C	C	C	C
13	NCA01	Nickel cobalt aluminium	13.5kWh	Battery Pack	C	C	-	-	-	-
14	LFP03	Lithium iron phosphate	2.4kWh	Battery Pack	C	C	C	C	C	C
15	NMC03	Nickel manganese cobalt	7.4Wh	Single Cell / cylindrical	C	C	C	C	C	C
16	NMC04	Nickel manganese cobalt	1.94Ah	Single Cell / cylindrical	C	C	C	C	C	C
17	LMO01	Lithium manganese oxide	2.38Ah	Single Cell / cylindrical	C	C	C	C	C	C
18	NMC05	Nickel manganese cobalt	2.5Ah	Single Cell / cylindrical	C	C	C	C	C	C
19	LFP04	Lithium iron phosphate	65Wh	Single Cell / prismatic	C	C	C	C	C	C
20	LFP05	Lithium iron phosphate	12.5Ah	Single Cell / cylindrical	C	C	C	C	C	C
21	LFP06	Lithium iron phosphate	2.5Ah	Single Cell / cylindrical	C	C	C	C	C	C
22	LMO02	Lithium manganese oxide	3.0Ah	Single Cell / cylindrical	C	C	C	C	C	C
23	LTO02	Titanate	1.35Ah	Single Cell / cylindrical	C	C	-	-	C	C
24	LTO03	Titanate	20Ah	Single Cell / cylindrical	C	C	C	C	C	C
25	NCA02	Nickel cobalt aluminium	2.85Ah	Single Cell / cylindrical	C	C	C	C	C	C

C- completed, '-'denotes where an asset has failed or testing has not been possible (further details can be found in the interim battery testing report).

- Profile 1: maximum power test and sustained power test
- Profile 2: energy, capacity and efficiency
- Profile 3: solar energy shift profile
- Profile 4: solar energy shift profile with VPP operation
- Profile 5: Accelerated solar energy shift profile
- Profile 6: Accelerated solar energy shift profile test with VPP operation

Specific reports that were developed describing the battery testing activities are described following.

Table 5: Battery testing reports overview

Report title	Description
Battery selection report [7]	This report describes the process and criteria developed to select the BSE to be used to validate the test profiles to be tested. Two version of the report exist: • Full report: This is the full version of the report with all details • Summary version: This is a summary version of the full report
Battery Calibration Report [8]	The battery calibration report describes the initial tests undertaken on the procured BSE to determine actual power, capacity and energy values when new.
Interim testing report 1 [9]	This report provides an update on the testing activities undertaken up to the end of milestone 3.
Interim testing report 2 [10]	This report provides an update on the testing activities undertaken up to the end of milestone 4.
Interim testing report 3 [11]	This report provides an update on the testing activities undertaken up to the end of milestone 5.
Final testing report [12]	This report provides an analysis of the complete testing undertaken as part of this Project.

3.2.3 ABPS and Industry Best Practice Guide

Under the Project, the Project Consortium prepared the ABPS and Industry Best Practice Guide. When preparing these documents, the Project Consortium undertook a significant amount of industry consultation in the form of workshops, webinars, one-to-one industry consultations and more (further information is detailed in Section 4). In progressing the Project, the Project Consortium understood (as noted on the Standard's Australia website), that standards development is typically a lengthy process, as shown in Figure 5. However, with the large amount of work and industry liaison already undertaken by the Project Consortium to develop this ABPS and Industry Best Practice Guide, it is hoped that the Standards Australia adoption process will proceed relatively quickly compared to a typical standard development process.

The Project Consortium developed a close working relationship with Standards Australia from the inception of this Project, given it was the intended recipient of the project outcome. The ABPS was submitted to Standards Australia on the 21st of May 2020 to go through its standard development process[11].

The most recent update from Standards Australia is that the submitted APBS project proposal is currently being reviewed by industry stakeholders to determine whether it should proceed to the project kick-off stage. Based on the feedback from the industry stakeholders together with its own internal due diligence, Standards Australia will determine whether or not to approve the drafting of the proposal. If a decision is made to approve the drafting of the proposal, then the standard development process will continue through the steps depicted in Figure 5.

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[11] For more information, refer to https://www.standards.org.au/standards-development/developing-standards/process

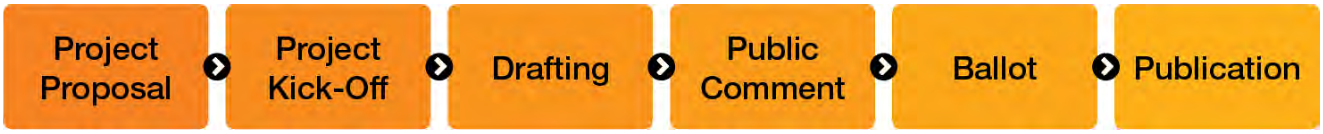

Figure 5: The six main stages in the development of an Australian Standard [12]

The APBS project proposal [13] provides testing methodologies and testing protocols for the measurement and reporting of the performance characteristics of BSE designed to be used within residential or small-scale-commercial applications in conjunction with solar PV systems. The ABPS is applicable to both DC and AC systems. It is intended to provide standardised testing and reporting requirements for the performance of BSE.

To support the ABPS, the Project Consortium has also released an interim Industry Best Practice Guide [14], which is intended to be used until such time as the Standard is released. The Industry Best Practice Guide contains the same information as the ABPS, including a step-by-step description of how to carry out the necessary testing, as well as background information on how to claim compliance until the Standard is released by Standards Australia. The Industry Best Practice Guide was finalised on the 15th of June, with a public release expected shortly thereafter upon which industry can adopt this on a voluntary basis.

By releasing the Industry Best Practice Guide, it is expected that the guide will assist and ensure the industry prepares not only for the likelihood of the release of an appropriate Standard to measure performance metrics of BSE, but also educate them on the key reasons why this is needed. In addition, the Industry Best Practice Guide helps to show what performance metrics will likely require standardised testing, the cost considerations for testing them and how this helps the customers to make informed buying decisions.

3.3 Stage 2: Other project deliverables

In the course of this Project, the Project Consortium prepared several other stand-alone documents[13] that did not form part of the ABPS and Industry Best Practice Guide. This section covers the information pertinent to:

- ✓ Development of a battery capacity estimation methodology
- ✓ Development of recommended criteria to select a battery management system (BMS)
- ✓ Recommend minimum set of information for safety data sheets (SDS)
- ✓ Development of a process to identify performance related hazards

3.3.1 Development of a battery capacity estimation methodology

One of the most important parameters of a battery is its capacity. Accurate estimation of capacity is imperative for the design of an energy management system (EMS) in a PV-battery system to ensure maximum utilisation of solar energy and longevity of the battery.

While there are several methods to estimate battery capacity, each has its advantages and drawbacks. Optimisation of these is the intellectual property of manufacturers and is closely guarded in commercially available systems. Therefore, as a part of this project, a team at Deakin University set out to develop a generic battery capacity estimation methodology that can be used by anyone. The aim was to develop an accurate,

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[12] https://www.standards.org.au/standards-development/developing-standards/process

[13] Which were originally proposed by the industry during the project inception stage

chemistry agonistic battery state of charge (SoC) estimation technique, which in turn can then provide an estimation of the remaining dynamic capacity of a battery.

To this end, many activities were undertaken from milestone 1 through to milestone 4. In the first milestone of this Project, Deakin University undertook an in-depth literature review on existing battery capacity estimation methodologies. From this literature review, it was concluded that among the existing methods, the Coulomb Counting (CC) approach was the most suitable method, considering its simplicity, ease of implementation and chemistry agnostic features. However, it was identified that this approach incorporates some challenges (e.g. measurement errors, self-discharge, lack of initial battery state of charge (SoC) knowledge, battery capacity degradation etc.) that affect its accuracy.

Therefore, during stage 2 of the Project, Deakin University developed an initial battery capacity estimation methodology by extending the CC approach, which overcame issues related to measurement error and self-discharge, and verified the results using the data provided by ITP Renewables[14]. Following this, the team further validated the proposed battery capacity estimation methodology in stage 4.A using the battery testing data generated by CSIRO as part of this Project. In the final stage of the project, the proposed methodology was further modified to overcome shortcomings related to a lack of knowledge around the initial battery SoC and battery capacity degradation, which was verified using CSIRO experimental test data and data provided by ITP Renewables.

An overview of the reports written while developing the battery capacity estimation methodology can be seen in the following table.

Table 6: Reports related to the development of a battery capacity estimation methodology

Report title	Description
A Comprehensive Review on Battery Capacity Estimation Methods [15]	This report provides a review of the various battery capacity estimation methodologies in use.
ITP Data Analysis Report [16]	In this report, an analysis of the data from the tests undertaken by ITP Renewables has been completed.
Battery Capacity Estimation Methodology and Validation using ITP data [17]	In this report, the initial battery capacity estimation methodology was tested and verified using ITP Renewables data, and existing shortcomings identified.
Interim battery capacity estimation methodology and validation using CSIRO data [18]	In this report, the initial battery capacity estimation methodology was tested and verified using data from the tests undertaken by CSIRO, and existing shortcomings identified.
Final Battery Capacity Estimation Methodology: Report on model validation with CSIRO test data [19]	This report describes the final battery capacity estimation methodology that was developed and its validation.

[14] https://itpau.com.au/

3.3.2 Development of recommended criteria to select a battery management system (BMS)

The purpose of this document was to describe the minimum set of criteria recommended for battery management systems (BMS) connected to BSE intended for use with domestic and small commercial solar PV systems [20]. This BMS criteria guide was designed to assist with the choice of third party commercially available BMS for integration with solar PV connected batteries. This guide is designed to help readers identify the ideal technological requirements the BMS should have for system development.

Furthermore, it was intended to assist existing BSE manufacturers in determining the best practices for future product development. This guide also highlighted gaps in current BMS reporting, which battery users have identified to assist both custom designers, integrators, and also current BSE manufacturers to provide state-of-the-art information as requested by current users.

This recommended practice may assist the interested parties in the following ways:

- By highlighting how different battery management systems can be compared on a like-for-like basis
- By defining information that is to be provided by BMS manufacturers to help installers, utilities, etc.
- Standardising the reporting to allow BMSs to be benchmarked against others
- Simplifying the process to understand BMS suitability into third party battery storage equipment
- By providing an educational guide to interested parties (such as governments, researchers, etc)
- Allowing manufacturers to demonstrate that their product meets the minimum set of recommended criteria for BMS in terms of safety, performance, etc.

3.3.3 Minimum recommended information for Safety Data Sheets

The report on the mminimum recommended information for Safety Data Sheets [21] was written to provide supporting information to industry and stakeholders developing BSE. Battery safety is a critical requirement for any system sold in Australia. Although a range of documentation exists, as well as Standards, covering aspects of safety, there are a number of gaps and challenges where information is limited or missing. This document was written to provide information to assist industry and stakeholders where gaps in safety information currently exist.

The document focussed on providing safety information and recommendations to users and consumers for the transportation and storage, decommissioning, recycling, first responders and certification segments of the BSE supply chain.

In this document, a number of gaps and areas where safety information is required or advisable have been identified for different points in the BSE supply chain. Based on these, a range of recommendations have been made to assist the industry. Although those were not comprehensive and improvements could be made, the recommendations serve to provide a starting point for future safety improvements.

3.3.4 Development of a process to identify performance-related hazards

The scope of this work was included as part of the Project (during the project concept phase in 2017) in response to specific industry requests. However, the industry has made significant progress in addressing battery safety-related issues since the inception of the Project. In the Australian context, deployment of the standard "AS/NZS 5139:2019: Electrical installations - Safety of battery systems for use with power conversion equipment" [22] can be considered as the most relevant document to the storage industry in general.

As noted, in the time since the concept and scope of the Project were developed and implemented, numerous agencies and advisory bodies have developed a range of documentation. The BSE performance related hazard identification process document [23] serves to outline the safety considerations for various residential and commercial energy storage technologies, and where further information can be found. It also addresses standards and regulations that are available in the area of energy storage that, in particular, covers the operational safety of energy storage systems. The recommendations provided in this document, as far as practicable, reference the existing relevant recommendations in the other guides.

The information outlined in this document was based on a review undertaken of literature applicable to consumer BSE and the identification of current best practices from existing documentation.

4 KNOWLEDGE SHARING AND PROJECT PROMOTIONAL ACTIVITIES

There were several activities undertaken as part of the knowledge sharing and promotional activities. These include but were not limited to stakeholder reference group meetings, workshops, webinars, one-to-one industry consultations, newsletters, trade publications, conference presentations, social blogs and press releases. This section intends to provide a brief overview of the activities that were conducted during the Project.

Under each milestone, one SRG meeting was held either via face-to-face meetings or online. In addition to the stakeholder meetings, other communication activities such as industry workshops, webinars, industry conferences, and one -to -one based industry consultations were conducted. The complete list of activities that were undertaken can be found in APPENDIX II – COMMUNICATION AND KNOWLEDGE SHARING ACTIVITIES.

5 PROJECT GOVERNANCE

A Project Steering Committee was established to monitor and coordinate the progress of the Project to ensure it achieved the milestone deliverables and the project outputs and outcomes. Under each milestone, two steering committee meetings were held (with the exception of milestone 1 which had 1, and milestone 3 which had 3), and decisions were communicated to the Project Consortium members via meeting minutes.

The committee comprised representatives of the project participants as follows:

- ✓ DNV GL – Dr Graham Slack, Dr Nishad Mendis, Mr Felix Liebrich, Ms Catherine Williams
- ✓ CSIRO – Dr Anand Bhatt
- ✓ Smart Energy Council – Mr Wayne Smith
- ✓ Deakin University – Dr Enamul Haque and Dr Sajeeb Saha

In addition, one or more observers from both ARENA and the Victorian Government's Department of Environment, Land, Water, and Planning (DELWP) were present at all Steering Committee meetings:

- ✓ ARENA – Mr Con Himonas, Ms Kerrie Harding
- ✓ DEWLP – Mr Campbell Fox, Ms Daria Zhdanova

The Steering Committee meetings were conducted in the form of face to face meetings as well as online. A total of 10 Steering Committee meetings were held throughout the Project.

6 KEY PROJECT DELIVERABLES AND STATUS

As set out in the funding agency agreements, multiple key project deliverables were required throughout the Project. The majority of the project deliverables formed part of the knowledge sharing deliverables under the funding agencies agreements. All required project deliverables were completed and submitted as required. APPENDIX III – PROJECT DELIVERABLES OVERVIEW AND STATUS provides an overview of all project deliverables and their status.

Many other administrative materials have been prepared under each milestone and submitted to the funding agencies for consideration. All public deliverables can be found at http://www.dnvgl.com/ABPS.

7 KEY PROJECT CHALLENGES AND IMPLICATIONS

The nature of the Project was in research and development. Under each milestone, the Project Consortium experienced several challenges to particular milestones as well as to the Project as a whole. The key learnings are explained in the following section.

7.1 Key Challenges and lessons learnt

1. The stakeholder engagement process was more time-intensive than expected

The Project received feedback from some SRG members that the Project Consortium were asking too much from them, given their competing priorities. The SRG response rate to post SRG Meeting surveys was generally low. Therefore, the Project Consortium revised the original stakeholder engagement plan and limited the number of SRG meetings to one per milestone during the project execution phase. In this way, it was able to maintain the dynamics of the stakeholder member interaction within the group.

In addition to engagement with stakeholders through the SRG, workshops and webinars, the Project Consortium has also sought feedback on a one-to-one basis. Together with our own knowledge and judgement, this helped to determine the best path forward for the Project.

As the Project entered its final stages, stakeholders became more engaged. This was not surprising as the Project started to become a reality for stakeholders and the affect it would have on them, while the documentation produced was close to being finalised. With the COVID-19 economic shutdown, the stakeholder engagement moved to online one-on-one meetings and this proved to be very successful at obtaining specific feedback.

It should be noted however that one-on-one meetings, while valuable at getting feedback, were also time intensive and this needs to be taken into account if planning them. Not only is there time required for each meeting, additional time to evaluate each piece of feedback relative to other feedback received is required, as well as to extricate any bias in feedback received.

2. Budget (consortium time or cash) related to third party data access was not fully accounted for in the initial planning

During stage 2, it was identified that real-life battery operational data, which was vital for characterising the battery use cases, was difficult to obtain, and may potentially have to be bought. However, the Project Consortium managed to have successful discussions with some industry partners to obtain real-life battery operational data. As a result, the Project Consortium received some useful battery use case data from some industry partners. However, due to the commercial sensitivity around the data, some industry partners determined not to provide the data and others conditionally agreed subject to execution of non -disclosure agreements (NDAs). The negotiation of the terms and conditions within NDAs generally took far longer than anticipated, and ample time should be allowed for this activity.

In retrospect, if these data requirements had been contemplated at the inception of the Project, a similar model, as implemented with ITP Renewables, would have been adopted early on to avoid such bottle necks.

3. Battery testing pathways and use cases

There were different views among the stakeholder members regarding the Standard testing protocols, battery energy storage system use cases and temperature and humidity profiles that could not be resolved before the initially planned start of testing. Without having a broader industry consensus on these aspects, project testing could not be initiated. To resolve this, an additional industry workshop was held at the CSIRO premises in Clayton with the SRG and other industry members (totalling 25) comprising a mix of industry participants including manufacturers, utilities, associations and others.

Three battery testing options were put forward to the industry stakeholders. These options were canvassed during the workshop and at the end of the testing pathways presentations, a participant survey on the options was conducted among the attendees.

Furthermore, the Project Consortium had previously identified 13 different potential battery use cases. During the workshop, the 13 possible BESS use cases for Australia were presented and discussed. Considering the time and cost associated with testing, the general consensus was that this was too many for inclusion in the ABPS as test protocols. The discussions converged on the opinion that the use cases should be reduced to between 1 and maximum 3 for inclusion within the ABPS.

As a result, the workshop was the appropriate mechanism to get the feedback required to develop a concise path forward for the project testing framework. However, as a result of the additional unplanned SRG meeting and relevant preparation required, the start of the testing process was delayed relative to the original plan, which required substantial effort to get back on track.

4. Battery system testing process

A number of challenges were faced with battery testing throughout the Project. For some systems, the onboard management software and design meant that utilising them for purposes outside of what they were designed to do makes communication and charging/discharging to specific profiles extremely difficult. The Project Consortium understands that this was also discovered by previous ARENA projects for the same battery systems. It took longer than expected to design customised testers and electronics to enable effective control of the units for testing. This has been overcome in the Industry Best Practice Guide by requesting that manufacturers supply the necessary hardware and software modifications (if required) to enable testing to be accomplished.

Secondly, it was found that the time allocated to testing should ideally have been longer. As the Project progressed with the testing, it was clear a range of systems/batteries were not performing as expected based on their datasheets. It took a number of replicate tests to determine that it was the actual units not functioning at the desired performance level as opposed to an issue with the test protocols themselves. If the Project Consortium were to redo this Project (without any time constraints), more time would be allocated during testing for this discovery process.

5. COVID-19 and project milestone 5 progress

In light of the COVID-19 pandemic, the government imposed general restrictions in mid-March 2020. As a result, it was anticipated that the battery project testing activities might be impacted due to the reduced staffing level at CSIRO testing facilities. However, CSIRO was able to complete the majority of battery testing activities, due to the remote operating capability of the battery testers in conjunction with rotating staff onsite to comply with social distancing requirements.

Although, a slowdown of stakeholder engagement activities due to the COVID -19 lockdown was anticipated, the resulting one-to-one based stakeholder engagement undertaken proved to be the most effective at obtaining feedback relative to other methods. Overall, COVID-19 had little impact on the project progress and the Project Consortium was able to complete all the planned activities with the exception of one industry presentation at an industry conference (which was postponed to outside of the Project timeframe).

6. Project collaboration

The large number of members in the SRG, which traversed a diverse group of industries, proved very useful in providing feedback from several different angles for the ABPS. Experts from many industries also helped to build knowledge and expertise within the Project Consortium. During SRG meetings, it also helped to put comments received into perspective of other industries, and were often discussed and tested within the meeting until a variation suitable to the majority of parties was found. As a result, the collaboration with a large range of stakeholders has been very beneficial to the outcome of the ABPS.

7. Some aspects of the Project required more time than expected

Some milestones were more time consuming than was forecast at the proposal development stage. This was partially been due to a number of documents that were required to be produced in addition to the base reports related to the key work undertaken on the Project. This included producing more documents for the additional workshop conducted to find a resolution to the ongoing debate on battery testing pathways (cell versus system level testing) during Milestone 3 (refer to point 3 above). This activity consumed a large number of man-hours from the Project consortium members. In addition, a considerable amount of time has been spent liaising with industry stakeholders to obtain real-life battery data (refer to point 2 above).

7.2 Implications for future projects

For future projects, the following implications should be considered and it is recommended that respective measures should be adopted to appropriately address them:

1. It is recommended that the amount of feedback to be obtained from industry throughout the course of a project should be kept flexible. This would allow the industry to engage more if willing, but wouldn't overburden them.
2. During SRG meetings, some SRG members were dominant in providing feedback to the Project Consortium. However, the Project Consortium was conscious that SRG member feedback often was from a particular perspective, and that in some cases it could be disadvantageous to other parties affected by the ABPS if implemented. As such, the Project Consortium had to evaluate, and at times, adjust the valuable feedback arising from SRG members in light of the overall project aim. This agrees with the advice provided to the Project Consortium at the inception of the Project by organisations who have had experience in developing such standards, namely that managing an external SRG can be both challenging and rewarding. As a result, it is possible that not all stakeholders will be comfortable with all conclusions from the Project.
3. Sufficient time should be allocated for preparing all milestone deliverables. This should include an allowance for multiple document reviews of any deliverables from project partners, preparation of additional documents that may help to progress the Project, etc.
4. Data collected by the industry on BSE use case profiles is commercially sensitive, is closely guarded and is not readily shared. An allowance in time and budget should be made for obtaining this sort of data if it is required as part of a project. This would help with successfully obtaining real use case data within the project schedule.
5. For some test objects, it would have been beneficial to have the manufacturer involved earlier in the experimental design and evaluation phases of testing the ABPS against their battery systems. To facilitate this, an appropriate budget should be allowed for.

8 CONCLUSION

The Project Consortium achieved the main aim of the ABPS Project, being to develop technology agnostic standardised testing and reporting requirements for the performance of BSE designed to be used within residential or small-scale commercial applications in conjunction with solar PV systems

The key deliverable achieved was the submission of the draft Standard to Standards Australia, for consideration as an Australian Standard. Given the extent of the stakeholder and industry consultation undertaken during the Project, the Project Consortium is of the view that the APBS makes a strong candidate for becoming an Australian Standard

The Project Consortium's extensive testing and analysis undertaken as part of the Project, covering a large suite of commercially available BSE, provides greater assurance and confidence that this will enhance the further consideration by Standards Australia as it undertakes a review of the technical aspects of the APBS. Until the Standards Australia process is completed, Australian industry can be guided by the Industry Best Practice Guide which can be found at APPENDIX I – ABPS AND INDUSTRY BEST PRACTICE GUIDE.

The Project Consortium is of the view that the Project and Standards Australia's enactment of the Standard will enable consumers to make informed decisions on the choice of BSE as it will be based on standardised testing and reporting requirements to express performance. Ultimately, the Standard could also help contribute to increased renewable energy penetration on the grid.

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APPENDIX I – ABPS and Industry Best Practice Guide

Attached to this report is the Industry Best Practice Guide, which has the same technical content as the ABPS submitted to Standards Australia.

APPENDIX II – Communication and knowledge sharing activities

Given the nature of the main deliverable, it was important that broad stakeholder feedback was received. The following tables provide an overview of the communication activities undertaken throughout the Project to support this work.

Table 7: List of Communication Activities

Activity	Milestone/Venue/Date
Stakeholder Reference Group (SRG) Meetings	
SRG Meeting 1	Milestone 1 (16 August 2018), CSIRO campus, Clayton
SRG Meeting 2	Milestone 2 (02 October 2018), Deakin University campus, Melbourne
SRG Meeting 3	Milestone 3 (02 April 2019), International Convention Centre, Sydney
SRG Meeting 4	Milestone 4 (03 September 2019), online videoconference
SRG Meeting 5	Milestone 5 (03 May 2020), online videoconference
Face to Face Invitation-only Workshops	
Workshop 1	Milestone 1 (12 November 2018), Engineers Australia, Melbourne
Workshop 2	Milestone 2 (09 May 2019), CSIRO, Clayton
Workshop 3	Milestone 3 (12 November 2019), Engineers Australia, Melbourne
Workshop 4	Milestone 4 (12 March 2020), CSIRO, Clayton,
Workshop 5	Milestone 5 (04 June 2020), Online
Webinars	
Webinar 1	23 November 2018
Webinar 2	20 June 2019
Webinar 3	12 December 2019
Webinar 4	15 April 2020
Conference Presentations	
Australian Clean Energy Summit 2018	31 July 2018, Sydney Convention and Exhibition Centre (ICC)
All Energy Conference	04 October 2018, Melbourne Convention and Exhibition Centre, Melbourne

Activity	Milestone/Venue/Date
Smart Energy Conference	02-03 May 2019, Sydney Convention and Exhibition Centre (ICC), Sydney
Queensland Smart Energy conference	08 September 2019, at the Royal International Convention Centre, Brisbane
Virtual power plants, new energy storage and renewable energy innovation global summit 2019	13/14 November 2019, the Hotel Windsor, Melbourne
IEEE IAS industry talk	07 November 2019, University of Melbourne, Melbourne
ICECIE 2019	27 November 2019, Malaysia

In addition to the above communicational/knowledge sharing activities, there were other promotional activities/materials, and one to one based industry discussions were also conducted. The summary of these activities is listed in Table 8.

Table 8: Promotional activities

<table>
<tr><th colspan="2">Promotional activities</th></tr>
<tr><td colspan="2">One to one industry consultations</td></tr>
<tr><td colspan="2">One on one consultation was undertaken with members from industry ranging across battery manufacturer’s to VPP operators to industry bodies. Each consultation was approx. 1 hour in length and focused on the ABPS and Industry Best Practice Guide.

One on one meetings were held between the 25th of February and the 9th of June 2020.</td></tr>
<tr><td colspan="2">Publications</td></tr>
<tr><td>Journal/Conference</td><td>Details</td></tr>
<tr><td>One step off the grid</td><td>Topic: World-first home battery performance guide submitted to Standards Australia

Published: 17 July 2020

Weblink: https://onestepoffthegrid.com.au/world-first-home-battery-performance-guide-submitted-to-standards-australia/</td></tr>
</table>

Promotional activities	
PV Magazine	Topic: New Battery Performance Standard proposed for Australia, and possibly the world Published: 16 June 2020 Weblink: https://www.pv-magazine-australia.com/2020/06/16/new-battery-performance-standard-proposed-for-australia-and-possibly-the-world/
RenewEconomy	Topic: Confused by the home battery market? This should help Published: 08 May 2020 Weblink: https://reneweconomy.com.au/confused-by-the-home-battery-market-this-should-help-65991/
IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), Macao, Macao	S. N. Islam, S. Saha, M. E. Haque and M. A. Mahmud, "Comparative Analysis of Commonly used Batteries for Residential Solar PV Applications," 2019 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), Macao, Macao, 2019, pp. 1-5 https://ieeexplore.ieee.org/document/8994441/
PV Magazine	Topic: Milestones passed on the road to an Australian Performance Standard for Battery Testing Published: 29 June 2019 https://www.pv-magazine-australia.com/2019/06/29/milestones-passed-on-the-road-to-an-australian-performance-standard-for-battery-testing/
Social Media promotions	
Australian Battery Performance Standard - Project Update	https://www.smartenergy.org.au/news/australian-battery-performance-standard-project-update-0
Australian Battery Performance Standard Project Update - December 2019	https://www.smartenergy.org.au/news/australian-battery-performance-standard-project-update-december-2019

Promotional activities	
Battery Standards on their way	https://www.smartenergy.org.au/news/battery-standards-their-way
Battery Performance Standards, Stakeholder Reference Group	https://www.smartenergy.org.au/battery-performance-standards-stakeholder-reference-group
One to one Industry discussions during MS-5	Twitter: https://twitter.com/DNVGL_Energy/status/1252441532491337728 LinkedIn: https://www.linkedin.com/feed/update/urn:li:activity:6658210173519261697/
DNV GL submits a Battery Performance Standard Proposal for Australia	https://www.linkedin.com/posts/dnvgl-energy_learn-more-new-battery-performance-standard-activity-6678495855311376384-S6Xa/
Press releases	
New Battery Performance Standard for residential and small-scale commercial applications proposed to Standards Australia (by DNV GL, 15 June 2020)	https://www.dnvgl.com/news/new-battery-performance-standard-for-residential-and-small-scale-commercial-applications-proposed-to-standards-australia-177568
DNV GL initiates energy storage standard for Australia (by DNV GL, 9 July 2018)	https://www.dnvgl.com/news/dnv-gl-initiates-energy-storage-standard-for-australia-125015
New Australian performance standards for home battery storage systems (by ARENA, 9 July 2018)	https://arena.gov.au/news/new-australian-performance-standards-for-home-battery-storage-systems/
$500,000 for DNV GL Australia through New Energy Jobs Fund (by ARENA, 29 June 2017)	http://www.jennymikakos.com.au/media-releases/500000-for-dnv-gl-australia-through-new-energy-jobs-fund/

DNV GL and CSIRO also created two Project specific websites to disseminate the project deliverables and battery test data to the public. Access to these websites can be found at:

- DNV GL: www.dnvgl.com/ABPS
- CSIRO: research.csiro.au/abps/

APPENDIX III – Project deliverables overview and status

Deliverable name	Description	Report number	Completion status
Milestone 1.A			
Battery selection report	Evidence that CSIRO have purchased batteries and the basis for their selection	PP198127-AUME-MS1A-TEC-01-R-01-A	100%
Battery selection report : Executive summary	Short report for public release (~2 pages): summary of Project, battery chemistry selections completed, tasks underway, technical reports to follow. For the general public.	PP198127-AUME-MS1A-TEC-03-R-01-A	100%
Milestone 2 – (Stage 1 Completion)			
Gap Analysis of Existing Battery Energy Storage System Standards - Summary Report Gap Analysis of Existing Battery Energy Storage System Standards	The Standards Gap Analysis Report (Stage 1 Public Report)	Summary report: PP198127-AUME-MS02-TEC-01-R-01-A Full public report: PP198127-AUME-MS02-TEC-06-R-01-A	100%
ITP Data Analysis Report	A Report on findings of a desktop analysis of battery performance data and outputs from the ITP Renewables Battery Testing Project ("ITP Test Data Evaluation report") (Stage 1 Public Report)	PP198127-AUME-MS02-TEC-03-R-01-A	100%
A Comprehensive Review on Battery Capacity Estimation Methods	The Battery Capacity Estimation Methodologies Literature Review	PP198127-AUME-MS02-TEC-05-R-01-A	100%
Milestone 3 – (Initial Progress on Stage 2 Activities)			
Battery Capacity Estimation Methodology and Validation using ITP data	Interim battery capacity estimation methodology and validation testing (discusses the algorithm development, status and validation against real-life battery performance data (ITP Renewables experimental data)	PP198127-AUME-MS03-TEC-01-R-01-A	100%

Deliverable name	Description	Report number	Completion status
Interim testing report 1	First Interim Report on Battery Testing Activities	PP198127-AUME-MS03-TEC-04-R-01-A	100%
Battery Performance Metrics and Load Report	Battery performance metrics and load Report - including discussion of the proposed load profiles identified from both literature (Stage 1) and real life data evaluation (Stage 2) and performance metrics which will be incorporated into the proposed ABPS after evaluating against battery testing for applicability.	PP198127-AUME-MS03-TEC-02-R-01-A	100%
Milestone 4 - Substantial Progress on Stage 2 Activities			
Interim testing report 2	The Second Interim Report on Battery Testing Activities	PP198127-AUME-MS04-TEC-01-R-01-A	100%
Recommended criteria to select a battery management system (BMS)	Report on the recommended criteria to select the Battery Management System (BMS)	PP198127-AUME-MS04-TEC-02-R-01-A	100%
Recommended Information for BESS and Battery Safety Information Sheets	Report on the recommended minimum set of information for Material Safety Data Sheets (MSDS)	PP198127-AUME-MS04-TEC-03-R-01-A	100%
Proposed Australian Battery Performance Testing Standard - for PV connected residential/small-scale commercial systems (Interim version) Australian Battery Performance Standard Industry Best Practice Guideline (Interim version)	Draft version (Interim) of the Proposed Australian Battery Performance Standard and Industry Best Practice Guidelines	Interim draft Standard: PP198127-AUME-MS04-TEC-04-R-01-A Industry Best Practice Guide: PP198127-AUME-MS04-TEC-06-R-01-A	100%

Deliverable name	Description	Report number	Completion status
Milestone 4.A- Methodology and validation			
Interim battery capacity estimation methodology and validation using CSIRO data	Interim battery capacity estimation methodology and validation testing (discusses the algorithm development, status and validation against real-life battery performance data (CSIRO experimental data)	PP198127-AUME-MS04.A-TEC-05-R-01-A	100%
Milestone 5- Project Completion			
Interim testing report 2	The third interim report on battery testing activities	PP198127-AUME-MS05-TEC-08-R-01-A	100%
Battery Storage Equipment performance related hazard identification process	Final Report on Performance-related hazard identification process	PP198127-AUME-MS05-TEC-01-R-01-A	100%
Final Battery Capacity Estimation Methodology: Report on model validation with CSIRO test data	Final Battery Capacity Estimation Methodology Report on Model Validation with CSIRO Test Data	PP198127-AUME-MS05-TEC-02-R-01-A	100%
Final Report on Battery Testing Activities	Final Report on Battery Testing Activities	PP198127-AUME-MS05-TEC-03-R-01-A	100%
Final Project Report	Final Project Report (This report)	PP198127-AUME-MS05-TEC-05-R-01-A	100%