April 2022

Zero Emission Flight Infrastructure

Standards Analysis and Strategy

Definitions and Acronyms

ABNT	Brazilian Association of Technical Standards
ABYC	American Boat and Yacht Council
AfK	Arbeitsgemeinschaft DVGW/VDE für Korrosionsfragen
AGFW	The German Energy Efficiency Association for Heating, Cooling and Combined Heat and Power (CHP)
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
API	American Petroleum Institute
AS	Standards Australia
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWI	Architectural Woodwork Institute
BAAINBw	The Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support
BNQ	Bureau de normalisation du Québec
BSI	British Standards Institute (publishes standards as "BS")
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CGA	Compressed Gas Association
CiA	CAN in Automation (CiA)
CLC	CENELEC European Committee for Electrotechnical Standardization
CPC	Connected Places Catapult
CSA	Canadian Standards Association
CTA	Consumer Technology Association
CWA	CEN Workshop Agreement
DIN	DIN German Institute for Standardization
DVGW	German Technical and Scientific Association for Gas and Water
ECSS	European Cooperation for Space Standardization
EI	Energy Institute
ETSI	European Telecommunications Standards Institute
FGW	Fördergesellschaft Windenergie und andere Dezentrale Energien
GB	Standardization Administration of the People's Republic of China
GOST	Federal Agency on Technical Regulating and Metrology
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IEEE	IEEE The Institute of Electrical and Electronics Engineers, Inc.
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JIG	Joint Inspection Group
JS	Jordan Institution for standards & metrology
JSA	Japanese Standards Association (publishes standards as "JIS")
KATS	Korean Agency for Technology and Standards (publishes standards as "KS")
NACE	National Association of Corrosion Engineers
NECA	National Electrical Contractors Association
NEMA	NEMA National Electrical Manufacturers Association
NEN	Royal Netherlands Standardization Institute
NFPA	National Fire Protection Association
NISTIR	National Institute of Standards and Technology Interagency or Internal Report
NZS	Standards New Zealand
OVE	Austrian Electrotechnical Association
PAS	Publicly Available Specification (published by BSI)
SABS	South African Bureau of Standards (publishes standards as "SANS")
SAE	Society of Automotive Engineers, Inc.
SCTE	Society of Cable Telecommunications Engineers
SFS	Finnish Standards Association
SNV	Swiss Association for Standardization (SNV)
STANAG	Standardisation Agreement (published by the NATO Standardisation Office)
TSE	Turkish Standards Institution
UL	Underwriters Laboratories Inc.
UNE	Spanish Association for Standardization
US DoD	US Department of Defense
UTE	French Standards
VDE	Association for Electrical, Electronic & Information Technologies
VDI	Association of Engineers
VdTÜV	Association of Technical Inspection Agencies
ZEFI	Zero Emissions Flight Infrastructure

Connected Places Catapult (CPC)

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Over 95% of BSI's work is on international and European standards. In its role as the UK National Standards Body, BSI represents UK economic and social interests across the international standards organizations ISO, IEC, CEN, CENELEC and ETSI, providing the infrastructure for over 11,000 experts to work on international, European, national and PAS standards development in their chosen fields.

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Contents

Table of Figures

Executive Summary

This report sets out key findings from a review of global standards to provide recommendations on a standardisation programme that would enable the safe and effective development of Zero Emission Flight Infrastructure (ZEFI).

The future of flight faces a number of principle challenges. Decarbonisation imperatives, wider sustainability challenges, meeting the climate action targets reiterated at COP26 and the UK's ambitious net zero commitment, as well as addressing the socio-economic impacts that airports have on communities, the physical infrastructure and on their supporting industries. These set the context of and raise fundamental issues to the net zero transformation path of aircraft as a mode of transport; and require a collective, coordinated, and strategic response.

The Zero Emission Flight Infrastructure (ZEFI) programme funded by the Department for Transport, is bringing together government, industry, regulators and academia to understand better the infrastructure changes required at airports and airfields to prepare for hydrogen-powered and battery electric aircraft.

This report provides a comprehensive review of the current standards framework relating to Zero Emission Flight Infrastructure (ZEFI) technologies and identifies the key knowledge gaps and requirements for new standards development, using both a quantitative and qualitative approach. This includes identifying standards that address safety requirements, interoperability, performance, management, and technology operation within a developing net zero aviation infrastructure. **This research has identified around 553 relevant standards, however only just over 20% of these are deemed as potentially directly applicable for ZEFI applications**.

Whilst there is a strand of relevant standards that begin to form a foundation on which to develop, there is a significant body of standardisation activity from other sectors including hydrogen production, hydrogen storage, pressurised systems, energy storage, battery management, electric vehicles as well as safe operational practice that can provide transferable knowledge to support standardisation of zero emission flight infrastructure.

This ZEFI Programme delivers on the Government's commitment in the Ten Point Plan for a Green Industrial Revolution to invest in R&D into the infrastructure upgrades required at UK airports to transition to hydrogen-powered and battery electric aircraft. General Aviation airfields, medium-sized regional airports and major commercial airports will need to service different aircraft types with parallel technologies.

Early strategic thinking suggests a number of interlinking areas to be addressed through which a viable infrastructure could be developed to support net zero aviation in a timely and efficient manner:

Figure 1: Blueprint for zero emission flight infrastructure, Connected Places Catapult

This research highlights the need for 5 interlinked standardisation activities and aligned to pillars of intervention to support the establishment of a net zero emission flight infrastructure. The following describes the future standards activities proposed on a short, medium and long term:

Stage	Timescale*	Activities
1. Enabling future standards	Short term (1 year)	Developing an aviation standards community for ZEFI Defining overarching principles and outcomes for ZEFI standards Prioritising future standards work Developing a long-term standards roadmap Establishing ZEFI standards steering group Establish ZEFI strategic programme advisory group
2. Defining future standards	Short term (1 year)	Assessing feasibility of how existing standards might be adapted from other industries Defining/wireframing core operational principles and design/performance specifications Support and align with aviation regulatory environment for ZEFI Defining proposals and justification for future standards development work
3. Mobilising standards development	Medium term	Commence standards development for Hydrogen including: • Quality and purity specifications • Foundational guidance to support capability level 1 • Refuellers and dispenser vehicle standardisation • Storage and management • Governance requirements and arrangements for operations, safety and security Commence standards development for Electric including: • Supply to aircraft • Governance requirements and arrangements for operations, safety and security

Stage	Timescale*	Activities
4. Adapting standards for ZEFI	Medium to long term	Adapting existing Hydrogen standards for ZEFI including • Liquefaction standing instructions / local procedures • Establishing working groups to consider future requirements Adapting electric standards for ZEFI including: • Energy storage • Battery storage • Distribution • Governance requirements and arrangements for operations, safety and security • Alignment with work in Faraday battery challenge
5. Developing forward programme	Long term	Developing the longer-term strategy and roadmap including considering: • Horizon scanning and landscape review to consider emerging work • Tracking technology development and aligning need for standards • Signposting and awareness raising • Support for implementation • Engagement with regulators

A more detailed description of the above proposed actions are provided in section 12 Recommendations.

It should be noted that the ZEFI standards roadmap programme will need to be refreshed regularly (e.g. every 1-2 years) to ensure it remains relevant and can respond to the needs of industry, technology maturity, policy requirements and other external factors and lessons learnt.

These integrated recommendations support a 'systems thinking' and a 'risk-based' approach that correlates well with the proposed areas of intervention included in Figure 1 above. Whilst there are clear primary work areas for Standards bodies to engage in i.e. working with Government policy on required standards research/regulation as well as specific standard development with the aviation industry - in reality, the development of standards links to and supports **all 6** proposed interventions.

Taking this systems perspective also supports the development of capacity and capability levels as addressed in **sections 9** and **11**. A **systems thinking** and **risk-based** approach identifies that standards are required prior to the implementation of the operating concept to make it feasible and legally supported.   Hence, this approach supports the overall ZEFI roadmap in two keyways.

First by de-risking threat or delay. Addressing specific standards gaps and topics directly de risk threat or delay to the development of this technology and its infrastructure. Innovation and investment become easier when its known there is the beginnings of a safety net to support and guide.

Second as an enabler Through developing the knowledge capital for standards that will need to rapidly advance the technology infrastructure capability and to act as a convener for international collaboration on the strategic and systemwide implications for the net zero aviation infrastructure.

Incorporating standards development into a future strategy means that the UK will be well prepared and well served by its own industry being positioned to contribute to this vital agenda.

Alongside helping define the technical specifications required to enable the ZEFI infrastructure development, this standards programme would have wider benefits and impacts including:

- Improved aviation industry collaboration through creation of a zero emission flight standards community and liaison with the existing aviation standards development community to coordinate efforts'.
- UK leadership of international standards, optimising market opportunities through efforts to align standards with UK industry offering.
- Interoperability of solutions across borders.
- Consistency in the consideration of operations, safety, security and performance requirements.
- Alignment with best practice available in other industry sectors and as considered against an emerging Operational Concept
- Ensuring the UK has the standards needed to support larger scale roll-out (e.g. enabling certification / type approvals).

Whilst we do not have data and analysis to consider the economic impact of standards for ZEFI, analysis undertaken by CEBR in 2015 to look at the economic benefits of standards more broadly identified that at a macro level, standards have the following benefit:

- Standards contribute towards 28.4% of annual UK GDP growth, equivalent to £8.2 billion in 2013;
- 37.4% of UK productivity growth can be attributed to standards;
- £6.1 billion of additional UK exports per year can be attributed to standards.

1 Introduction

The Zero Emission Flight Infrastructure (ZEFI) Programme, led by Connected Places Catapult for the Department for Transport (DfT), aims to understand the airport and airfield infrastructure required to support hydrogen-powered and battery electric aircraft.

In 2019 the UK government committed to "ensure that the net UK carbon account for the year 2050 is at least 100% lower than the 1990 baseline"[I], and in 2021 this was extended to include the UK's share of international aviation emissions. In 1999, the Intergovernmental Panel on Climate Change (IPCC) stated that the gases and particles emitted by aircraft "alter the concentration of atmospheric greenhouse gases, including carbon dioxide (CO_2), ozone (O_3), and methane (CH_4); trigger formation of condensation trails (contrails); and may increase cirrus cloudiness – all of which contribute to climate change"[II].

Engagement with technology innovators, regulators, government bodies and the industry itself, concludes that the airport infrastructure must rapidly evolve to enable net zero aviation and to ensure the UK leads globally in zero emission aviation systems. Widespread adoption of Sustainable Aviation Fuel, hydrogen powered and battery electric aircraft is critical to achieving the UK's goal of reaching net zero in aviation by 2050. The government agenda expects to see hydrogen aircraft capable of up to 20 passengers to be operational within this decade by 2030 and for aircraft capable of carrying 20-150 passengers from 2030-2035.

Hence, planning the airport infrastructure for our net zero future must start now as it is likely we will see an increase in the complexity of airport operations. New technologies will need to work in parallel, replacing the mature aviation fuel infrastructure over time. This parallel operation will require multiple infrastructures, policies, procedures and teams to coexist.

The Zero Emission Flight Infrastructure (ZEFI) Programme, funded by the Department for Transport brings together government, industry, regulators and academia to understand better the infrastructure changes required at airports and airfields to prepare for hydrogen-powered and battery electric aircraft.

The ZEFI Programme examines the resulting variety of infrastructure requirements and explores a number of challenges highlighted to the development and introduction of this new infrastructure. It notes:
significant timescales from conception to operation of new airport infrastructure compared with the urgency to achieve net zero

- Various maturities of aircraft and airport infrastructure technologies and their interdependencies
- Construction and operation of new infrastructure while operating and maintaining existing infrastructure
- Funding in a challenging operating environment
- Few available standards, policies, procedures and training for the new infrastructure

This work is critical to inform and prepare the sector for urgently developing and delivering the innovations and systems that will make net zero aviation a reality. This report builds on the Zero Emission

Flight Infrastructure White Paper released by Connected Places Catapult[III] which provides an overview of the available technology options and highlights the key challenges that need to be solved.

I Climate Change Act 2008. 2008. https://www.legislation.gov.uk/ukpga/2008/27/contents
II D. Lister, D. J. Griggs, M. McFarland, and D. J. Dokken, 'Aviation and the Global Atmosphere: A Special Report of the Intergovernmental Panel on Climate Change', IPCC, 1999. https://www.ipcc.ch/report/aviation-and-the-global-atmosphere-2/
III https://cp.catapult.org.uk/news/zero-emission-flight-infrastructure-white-paper/#:~:text=The%20Zero%20Emission%20Flight%20Infrastructure,powered%20and%20battery%20electric%20aircraft

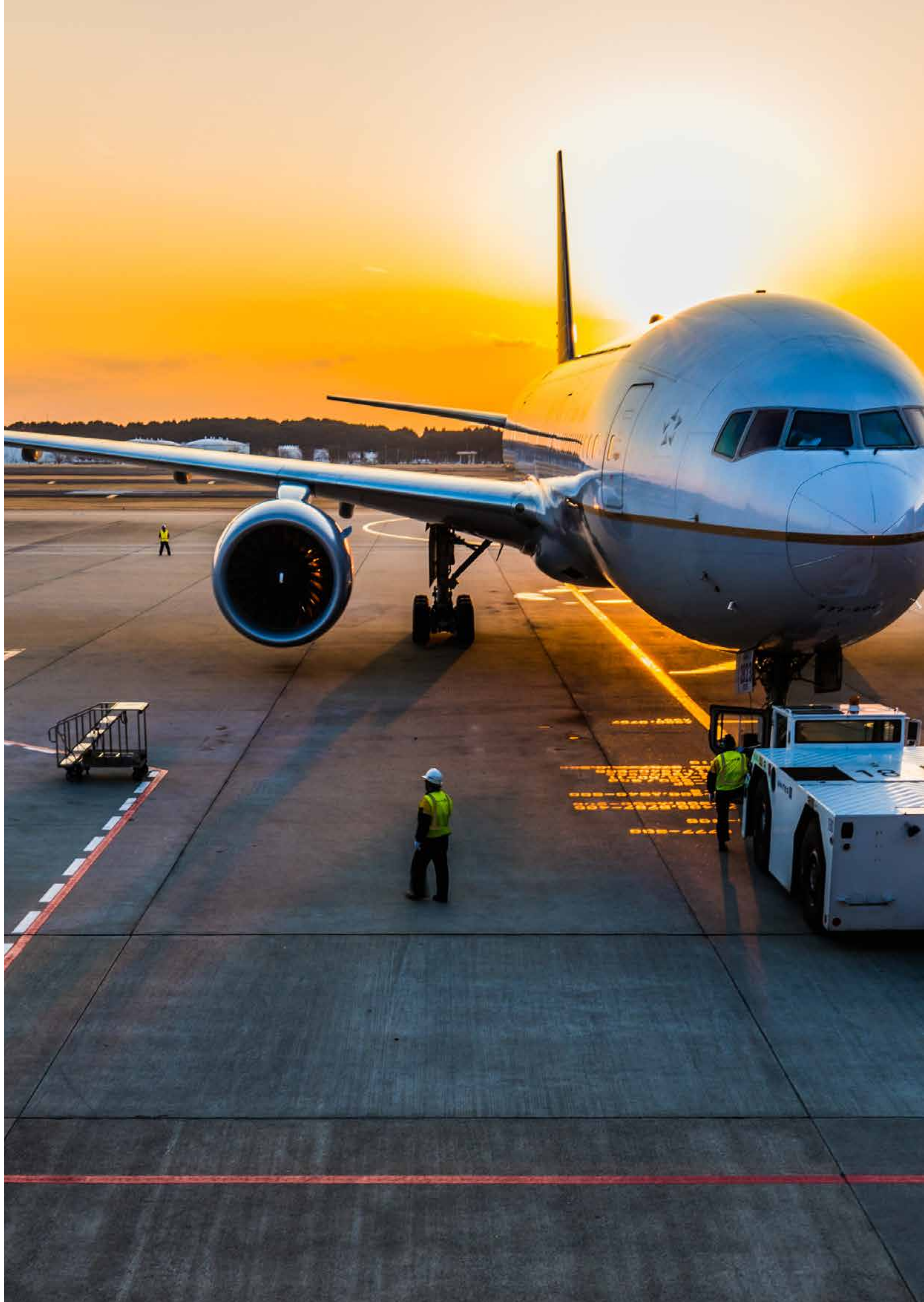
This work delivers the Government's commitment in the **Ten Point Plan for a Green Industrial Revolution** to invest in R&D into the infrastructure upgrades required at UK airports to move to battery and hydrogen-powered aircraft. Future aircraft types are expected to contribute significantly to the decarbonisation of aviation, as seen in the Sustainable Aviation Roadmap.[i]

The ZEFI Programme considers the fuel or energy flow from arrival at the airport to the connection to the aircraft. The electric and hydrogen supply chain outside the airport boundary and the design of zero emission aircraft provide context for the ZEFI Programme but fall outside the direct scope.

This document presents the findings of ZEFI Programme work package 10. This work package focuses on the following:

1. A landscape review of international standards currently available
2. A stakeholder review of the gaps identified in the existing standards framework
3. Focused in depth interviews on the challenges of developing net zero aviation infrastructure with participants from TRIG (Transport Research Innovation Grants) The TRIG sought commercial organisations and universities that are looking to develop technologies and solutions in a number of areas that will help the UK achieve Jet Zero. In particular, projects looked at the feasibility of integrating hydrogen and electric infrastructure systems in airfields.
4. Exploration of priorities for adaption or development of new standards according to
   - a. technology and operational need
   - b. the developing maturity of the airport operations for this new infrastructure
   - c. expectations for developing required infrastructure capabilities.

i https://www.sustainableaviation.co.uk/wp-content/uploads/2020/02/SustainableAviation_CarbonReport_20200203.pdf



2 Key findings

The standards landscape review and this subsequent report aims to identify where there are 'gaps' in standards and to highlight requirements for standards development. This includes both where no standards exist or where current standards are not suitable for ZEFI application. It therefore aims to highlight gaps where there is a need for standardisation activity to take place. It is noted that there is an existing set of standards within similar technology domains that provide some foundations and thematic strands to develop a standards framework to support the needs of this new infrastructure.

In our research we have identified there are existing committees in IATA, JIG, Energy Institute with experts who sit on various committees such as Technical Fuel Forum, Operations Committee, Filtration Committee, HSSE committee who will be key in helping to shape future standards for ZEFI.

The qualitative analysis, documented in Section 9, has identified several gaps and development areas in the standards landscape, including some prioritised areas that would benefit immediate consideration. This report concludes:

A number of gaps in standards exist in the management and use of hydrogen within of airport operational infrastructure. These include:

- Storage of hydrogen in liquid or gaseous form airside and landside within an airport boundary and use of refuelling vehicles to transport hydrogen
- Chemical hydrogen storage, hydrogenation and dehydrogenation within the airport boundary
- The development of a hydrogen pipeline, hydrant infrastructure within airports and technology into- plane fuelling
- Operational and safety management considerations of hydrogen supply; megawatt electrical supply and supporting infrastructure within an airport and its wider environment
- Management of battery; hydrogen fuel cell and hydrogen fuel tank swapping including the safe operational procedures for use of vehicles for inserting/removing batteries; cells; cylinders and tanks from aircraft

A number of standards exist both on a UK and international basis that could be adapted to support specific sub areas of focus required of the new infrastructure and its developing technologies. These include:

- Hydrogen: particularly onsite arrival, generation (electrolysis) within or close to an airport boundary and management of quality and purification of hydrogen for aviation purposes
- Electric: particularly around energy/battery storage, battery charging management and infrastructure, and high voltage (>500kW) electrical management in an airport setting
- Safe, secure operational governance: particularly on adaptation of pressurised process control systems and terminology (to hydrogen fuel cell systems) and adaptation of hydrogen instrumentation to an airport setting. In addition, the use of MSDS or Quality Certificate of hydrogen and Risk Assessment Management as a safe operating procedures and AVSEC/local airport standards on secure fuel management could be adapted to support these emerging technologies

The development of a net zero aviation infrastructure involves a complex web of technology development and integrating systems. These have been categorised into a specific areas of technology focus. However, adapting the standards suggested above needs to consider **what is most impactful to address the gaps** identified and **what is most important to achieve the best capability benefit** as part of strategically planned and commissioned infrastructure roadmap.

The prioritisation of which standards to develop is intrinsically linked to:

- Matching need for technology development to the current TRL status of the standards sub area of focus and expected trajectory /pathway
- Expected capability levels of airports as part of an overarching capability blueprint and developing maturity strategy
- Funding and investment opportunities available
- The development of standards must align with a longer-term strategic need of airports as national strategic infrastructure assets; their interface with the energy supply chain (through DOC investment strategies) as well as the planning policy and consultation required with the physical/geographical communities in which they sit

From this perspective choices must be made on the foundations available and what should be 'built from the ground up' in order to achieve the vision of a future operating concept.

Using the technical insight from engineering and technology leads within Connected Places Catapult; validated through discussion with industry representatives in stakeholder engagement workshops - a number of standards requirements were identified. These standards requirements and ensuing priorities were considered critical to safe operations of the infrastructure and enabling the future airport net zero capability development. These requirements and priorities can be matched with expectations for technology capacity and infrastructure performance linked to a zero aviation airport infrastructure capability levels (see sections 10 and 11.1). These directly related to pillars 2,3 4 and 5 of the zero emission flight infrastructure blueprint and include:

For hydrogen:

- **Arrival at site** - Standards to ensure the quality and purity specification of hydrogen /liquid hydrogen to the required parameters is essential
- **Refueller and supply to aircraft** - Standards to ensure the provision of refuellers and dispenser vehicles and which can assess and dispense on-spec fuel is critical to operations.

For electric:

- **Distribution to apron** - An upgraded cable network will be required to meet the power demand of the charging infrastructure and therefore existing standards will need to be adapted for expected demands or new standards created to support application in airport environment.
- **Supply to aircraft** - Standards to ensure having a fixed charging infrastructure capable of providing tens of kilowatts to megawatt capacity. This is a high operational priority

A review indicated that some standards designed for application in other use cases or industry sectors could be adapted to support ZEFI however this requires further detailed analysis, validation and verification. Additionally, various national and international Technical Committees exist in areas such as hydrogen safety, pressurised systems, battery management (e.g. lessons learned from the UK Faraday challenge) or electrical management which could support future standards adaption and revision requirements.

The research and this reports findings indicate areas of gaps in existing standards and the need for standards development to support the maturity of capability levels aligned to the operating concept model (see section 10). Whilst globally accepted standards should be considered the end-goal for the ZEFI programme, there are opportunities for the UK to demonstrate standardisation leadership in strategic areas of UK strength.

The global standards landscape is complex and future harmonization of standards may be needed to enable interoperability and the associated operational and standardization benefits this provides such as supporting cross border trade, international collaboration on knowledge sharing (promoting UK as a thought leader) circular economy (e.g. through material reuse), repairability and easier market access for new businesses.

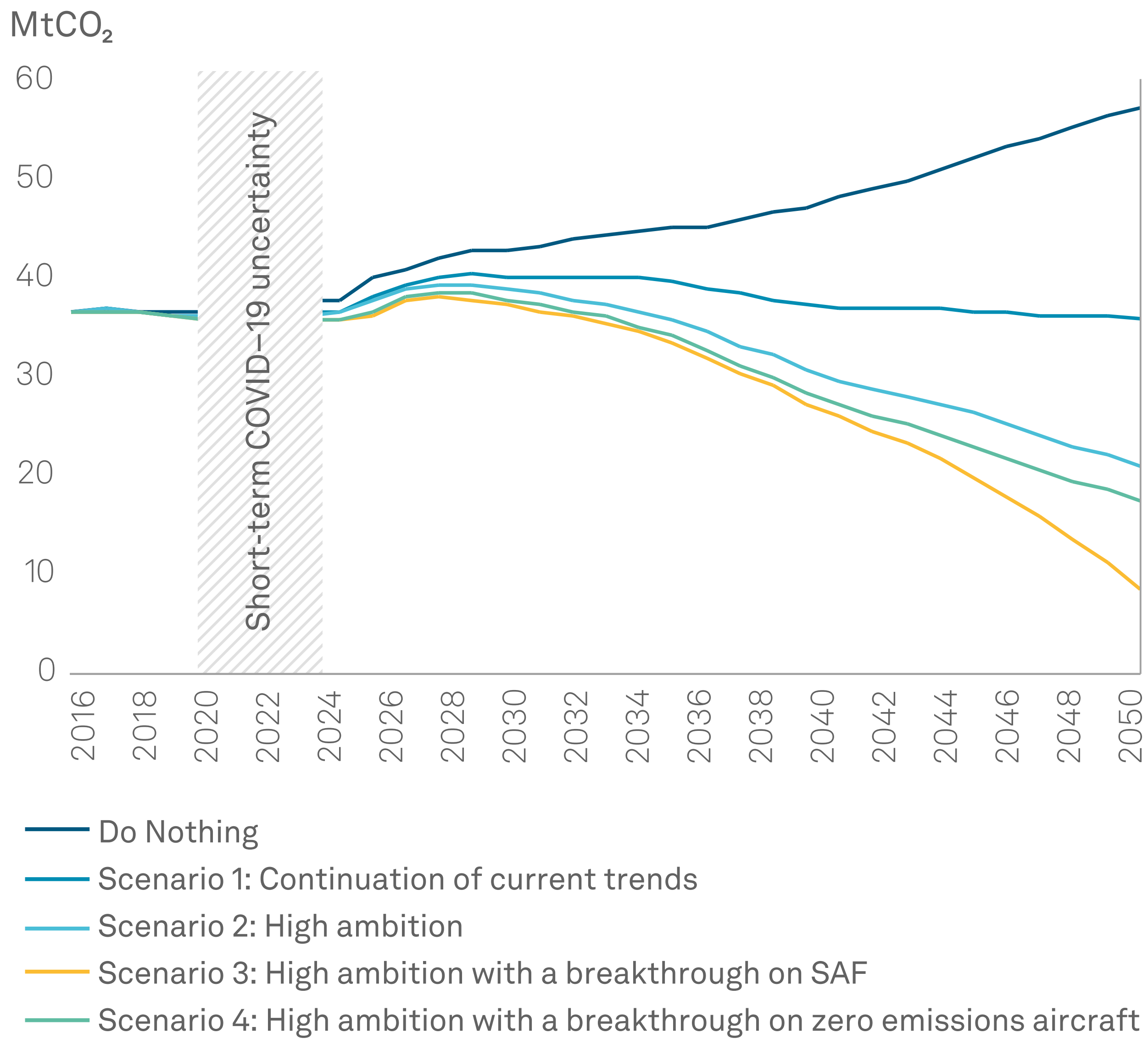
The report explores these findings and recommends strategic approach to standardisation development over the initial, short, medium, and long terms which are detailed in Section 12.

2 Project objectives

The UK Government's Net Zero Strategy states, "We will address aviation emissions through new technology such as electric and hydrogen aircraft, [and] the commercialisation of sustainable aviation fuels [SAF]..."[I]. The substantial adoption of SAF, hydrogen-powered and battery electric aircraft will be critical to achieving the UK's net zero goals.

The different scenarios for UK aviation decarbonisation are shown in Figure 1. Additional infrastructure, supporting systems and operations will be required at airports to realise the full potential of the opportunity.

Figure 2: Aviation decarbonisation scenarios[II]



I Net Zero Strategy: Build Back Greener. HM Government, 2021. https://www.gov.uk/government/publications/net-zero-strategy
II Aviation decarbonisation scenarios reproduced from the Department for Transport Jet Zero Consultation under the Open Government Licence v3.0 - 'Jet Zero Consultation: A consultation on our strategy for net zero aviation', Department for Transport, Jul. 2021.
https://www.gov.uk/government/consultations/achieving-netzero-aviation-by-2050

The goal of the ZEFI Programme is to explore the impact and requirements for fuelling infrastructure to introduce hydrogen and electric aircraft into airports

Early in the planning for the project it was agreed that the infrastructure for SAF would likely follow existing or adopted use of existing aviation fuel in restructures so SAF was not included in the scope of the international standards landscape research or as focus of this report.. The ZERO Emission White paper identified standardisation as one of the four key challenges to net zero aviation. The white paper noted:

> **"Standardisation efforts are in their early stages, for instance, the specification of charging and fuelling connectors. Flexibility in engineering and modular designs are encouraged to permit changes as the systems evolve. Organisations should engage and partner to define the required standards"**[I]

This reports addresses this challenge by providing a literature review of existing standards, engagement with stakeholders on needs and expectations of standards to support the infrastructure plus an evaluation of priorities and needs for the technology, systems and infrastructure required to support the ZEFI programme. Details of the scope, approach and methodology are detailed in the report sections below.

I https://cp.catapult.org.uk/news/zero-emission-flight-infrastructure-white-paper/#:~:text=The%20Zero%20Emission%20Flight%20Infrastructure,powered%20and%20battery%20electric%20aircraft

3 Standards roadmap scope

Work Package 10 comprises an international standards landscape review and gap analysis along with related stakeholder engagement to validate findings and to develop recommendations.

The following objectives were set for standards landscape work package:

- Undertake standards research and related activities /engagement to support the development and delivery of hydrogen and electrical infrastructure at airports
- Identify the issues and challenges for standards in supporting or adapting existing infrastructure and/or the creation of new airport infrastructure to support electricity and hydrogen powered flight
- Understand where standards are not present or inadequate for the handling of hydrogen and electricity in airside environments
- Inform future development of standards and their application to enable demonstrations and technology enhancement to further standards development

Specifically, this research and engagement focused on the two ZEFI supporting technology systems and their corresponding infrastructure areas:

- **Airport infrastructure systems for hydrogen powered aviation**, including: storage, handling, aircraft refuelling/defueling, distribution, and associated technologies. The associated infrastructure includes consideration of moving and handling gaseous and liquid hydrogen, and transition between these states.
- **Airport infrastructure systems for electric/battery powered aviation**, including: charging (including MegaWatt charging), storage, handling and moving batteries, electric distribution to the apron, battery management systems and associated technologies and processes. This includes infrastructure to support aircraft with chargeable or swappable batteries.

The scope for this research was defined from where the fuel (hydrogen or electricity) enters the outer perimeter of the airport, to the hose or cable that plugs/connects into the aircraft. Hence the infrastructure model identifies four key stages:

- Arrival on site
- Onsite storage and management
- Distribution to apron
- Fuelling/charging aircraft

Further explanation of this is set out in the report section 6 on the operating concept for airport infrastructure below.

4 Methodology

In developing this report, the following activities have been undertaken:

Agreeing scope for landscape review

An initial structure and definition of the areas of the ZEFI systems and standards approach was produced. This was based on understanding and analysis undertaken in co-ordination with the wider ZEFI Programme and industry knowhow, this included an analysis of the concept of operations.

Scoping workshop

The aim of this workshop was to build upon the initial project definition and further define the key areas of focus to use as a basis for the standards landscape research. The 2.5-hour workshop was held via Teams on 11th November 2021 with input from 21 leading industry stakeholders.

Quantitative analysis

- Standards Searches - The output from the Scoping workshop generated a comprehensive matrix of key words or terms in thematic areas, which enabled searches to be undertaken on standards databases and other reference materials.
- Standards analysis - Standards identified went through a classification and a high-level review to determine their relevancy to the strategic objectives of the project and to highlight critical standards.
- Standards landscape - The report provides a variety of insights based on standards metadata. It incorporates an interactive map of the standards which enables the user to explore the landscape, according to the areas of focus of interest, while uncovering the relevant metadata.

Structured interviews with TRIG participants and ZEFI demonstrator projects

Conducted four exploratory, in-depth interviews with Transport Research Innovation Grant winners (TRIG) and demonstrators to fulfil the following objectives

- To gather the learnings from the trial and demonstration activities
- To ascertain the industry challenges with existing standards
- To identify the key areas with standards gaps and the opportunities for new standards.

Qualitative analysis

Standards gap analysis - a qualitative analysis was carried out on the apparent standards coverage of the standards objectives, to identify and describe potential standards gaps.

Validation workshop

To validate the landscape and gap analysis, a second workshop was conducted to verify the gap hypotheses to feed into recommended standards development priorities (short, medium and long term) as part of a future standards roadmap development.

5 ZEFI operating concept for airport infrastructure

The infrastructure required to support Hydrogen and Electric aviation is very different to that for conventional aviation fuels. The focus of ZEFI is the infrastructure within the airport boundary, which can be split into four areas covering arrival to site, storage, distribution, and supply to the aircraft.

Figure 3 and Figure 4 highlight the core elements of the fuelling and energy management systems at a high level.

Each airport will have a subset of technologies depending on the type of aircraft airline/operator requirements, capacity and the routes supported. In addition, operators must also consider how supporting systems may change, such as maintenance and fire services.

Figure 3: Airport infrastructure systems for hydrogen powered aviation[I]

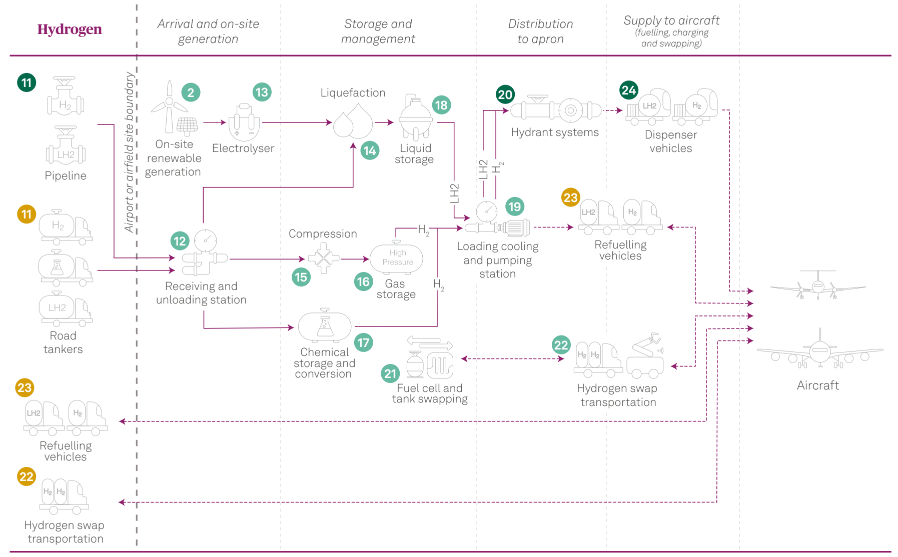
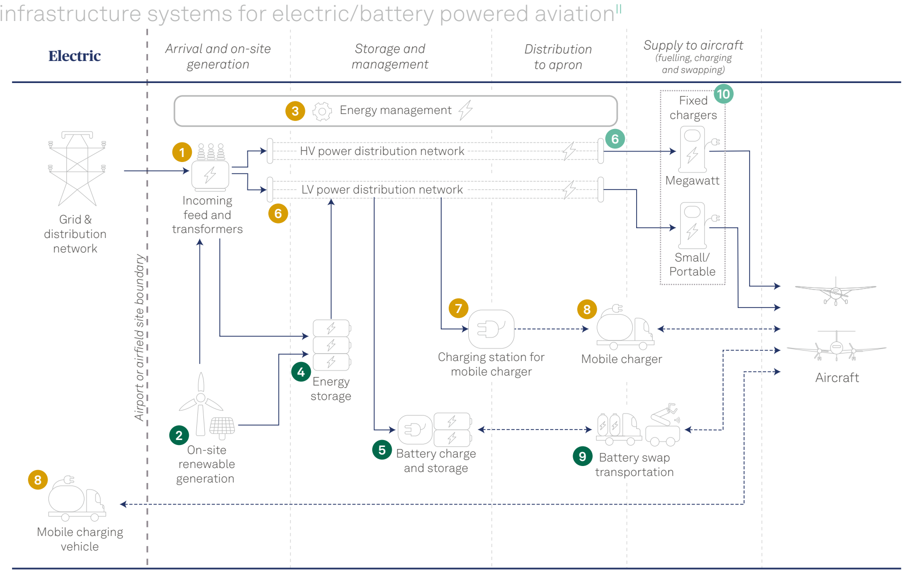


Figure 4: Airport infrastructure systems for electric/battery powered aviation[II]



A more detailed definition of the supply chain stages; hydrogen and electric, is included in Annex C.

I Taken from https://cp.catapult.org.uk/news/zero-emission-flight-infrastructure-white-paper/#:~:text=The%20Zero%20Emission%20Flight%20Infrastructure,powered%20and%20battery%20electric%20aircraft

II Taken from https://cp.catapult.org.uk/news/zero-emission-flight-infrastructure-white-paper/#:~:text=The%20Zero%20Emission%20Flight%20Infrastructure,powered%20and%20battery%20electric%20aircraftTechnoo

6 Standards landscape review – Quantitative analysis

Standards landscape scope and parameters

Standards type

The standards landscape captured two types of standards:

1 Formal standards - published by National Standards Bodies (NSBs) and Standards Development Organisations (SDOs).

1 Informal standards - published by industry bodies.

Jurisdictions

Standards from all available countries were included in subject searches, as well as those from European and International standards bodies, in order to maximise the capture of any relevant standards.[I]

"European standards bodies" refer to those whose remit extends across Europe (e.g. CEN/CENELEC, ETSI), and "International standards bodies" refer to those whose remit extends globally (e.g. ISO, IEC).

Many European and International standards identified for this project have been adopted by individual countries. However, adopted versions were removed from the final list of standards to avoid duplication, such that only the original standard was considered for analysis. For example, BS EN 17533 is not included in the dataset because it is a British adoption of EN 17533, which was kept in the results instead.[II]

Technology type

The searches and results were broken down based on whether they applied to hydrogen or electric power infrastructure and have subsequently been presented as such in this report. The distinction was useful from an early stage in the project because many of the relevant standards or areas of focus for each technology type do not overlap regarding ZEFI.

Supply chain stages and sub-areas of focus

The scopes for each technology were broken down into supply chain stages, as well as sub-areas of focus within those stages, in line with Figure 3 and Figure 4 in Section 6. Subsequently, keywords were identified for each sub-area of focus, and searches for relevant standards were conducted accordingly.

These supply chain stages and sub-areas of focus have been represented in Figure 5 and Figure 6 below, for both hydrogen and electric power.

I These countries were: Australia, Austria, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Italy, Japan, Jordan, Lithuania, Netherlands, Norway, Poland, Russia, Slovakia, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, and the United States

II Gaseous hydrogen - Cylinders and tubes for stationary storage

Figure 5: Supply chain stages and sub-areas of focus – hydrogen

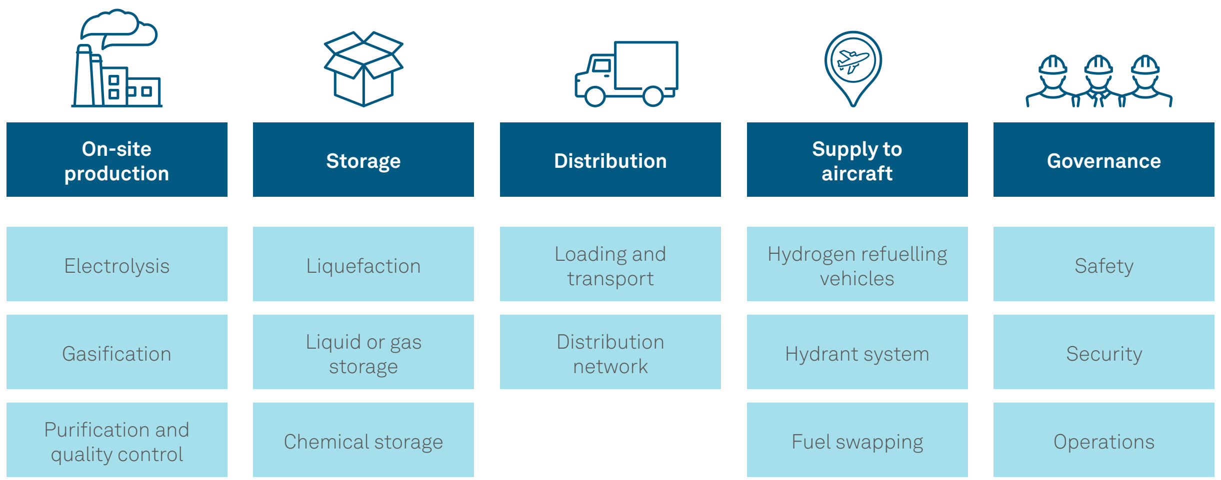
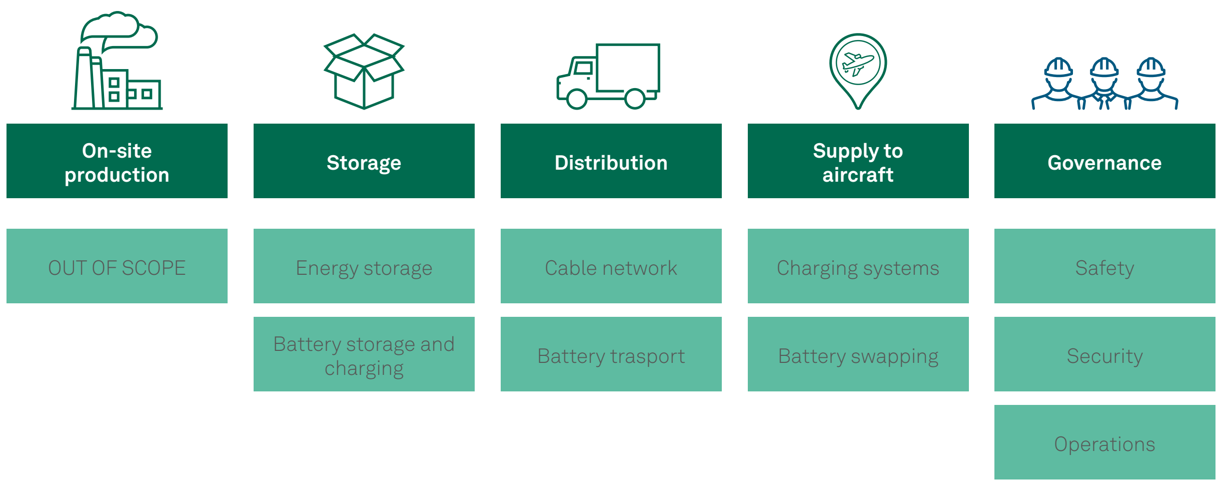


Figure 6: Supply chain stages and sub-areas of focus – electric



Presentation of findings - general narrative

The standards landscape findings for each technology type have been presented according to the following narrative:

Standards classified by relevancy

Standards searches were based on topics and keywords identified during initial exploratory research, taking into consideration findings from the Scoping Workshop on 11th November 2021. However, not all the results were of equal relevance, so a relevancy assessment was conducted, and standards were subsequently classified according to the following categories:

Highly relevant to ZEFI
Mostly applicable without change but requires further assessment.

Relevant
Could be transferable to ZEFI but currently applies to parallel or similar use-cases.

Somewhat relevant
Likely requires significant change as part of adaptation for ZEFI.

Not relevant
These standards were removed from the final dataset and not included in the analysis.

Standards landscape overview

An overview of how the results are spread across the different areas and sub-areas of focus (as defined in each respective matrix) is shown by a tree map.

Tree maps display hierarchical data as a set of nested rectangles. The size of each rectangle corresponds to the number of standards and provides an overview of which supply chain stages and sub-areas of focus contain the most and least number of standards.

Distribution of standards by relevancy

A more detailed look at how standards are spread across the landscape based on their relevancy is presented via a survey map. This shows where the more relevant standards have been found, as well as potential gaps in standardisation.

Standards by origin

The origin of relevant standards is helpful to know, so that future efforts in areas such as collaboration or monitoring of publications can be directed more effectively. This is presented via two different bar charts showing:

1. Which countries or regions have published the most standards of relevance to ZEFI;
2. Which committees have published the most standards of relevance to ZEFI.

Occurrences

Starting to look at standards more specifically, some appear more than once in the final dataset because they are relevant to multiple areas of focus. The frequency with which a standard appears and overlaps across the results is an indication of how specific or wide-ranging it may be.

Presentation of findings - Hydrogen

Standards classified by relevancy

Highly relevant to ZEFI
Mostly applicable without change but requires further assessment.

Relevant
Could be transferable to ZEFI but currently applies to parallel or similar use-cases.

Somewhat relevant
Likely requires significant change as part of adaptation for ZEFI.

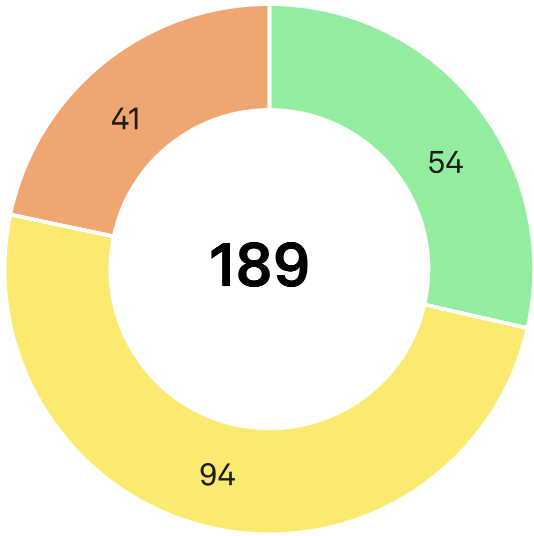


Figure 7: Standards classified by relevancy – hydrogen

A total of 189 unique relevant standards were identified across the ZEFI standards landscape for hydrogen power, 54 (29%) of which being highly relevant in their current form subject to further detailed assessment.

A total of 25 standards were returned more than once, as they applied across multiple supply chain stages or sub-areas of focus. The frequency with which a standard appears and overlaps across the results is an indication of how specific or wide-ranging it may be.

Those which occurred three times - more than any others - are:

- NF M58-003, "Installation of hydrogen-related systems".
- ISO/TS 19883, "Safety of pressure swing adsorption systems for hydrogen separation and purification".
- STANAG 3609, "Standards for maintenance of fixed aviation fuel receipt, storage and dispensing systems - AFLP-3609 Edition A".

It is worth noting that the potential breadth of these standards may not necessarily translate into importance for ZEFI.

Standards landscape overview

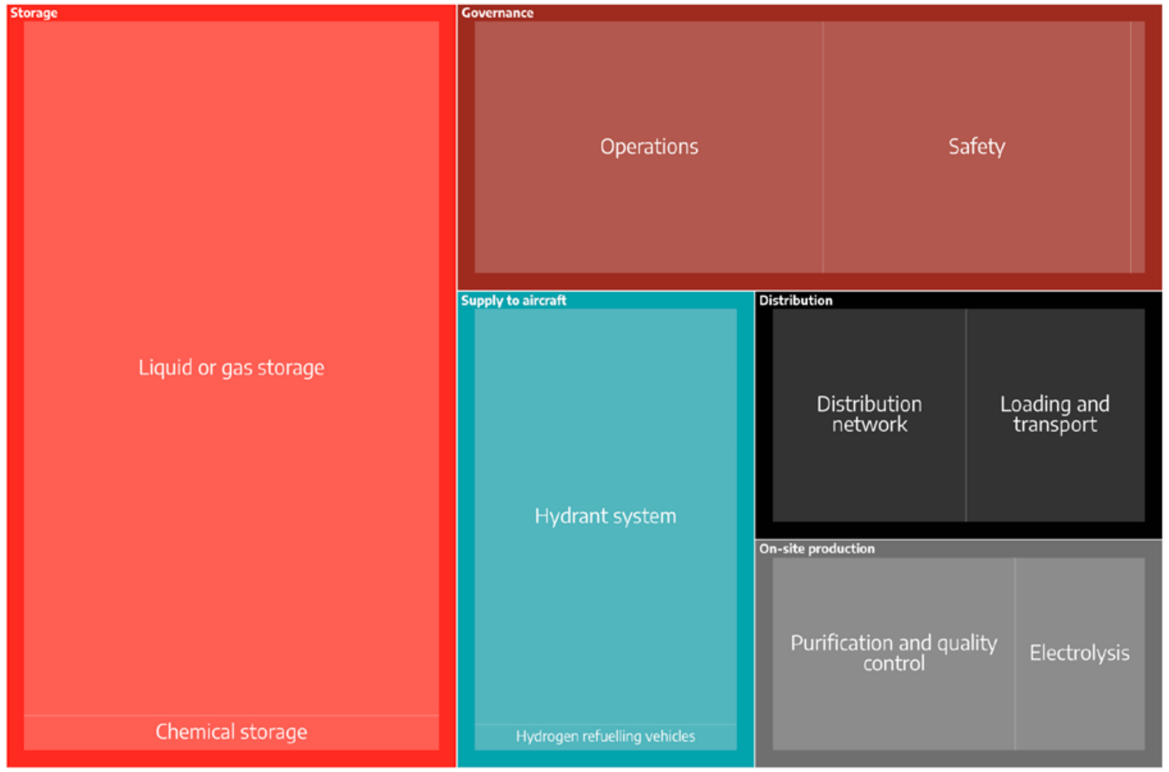


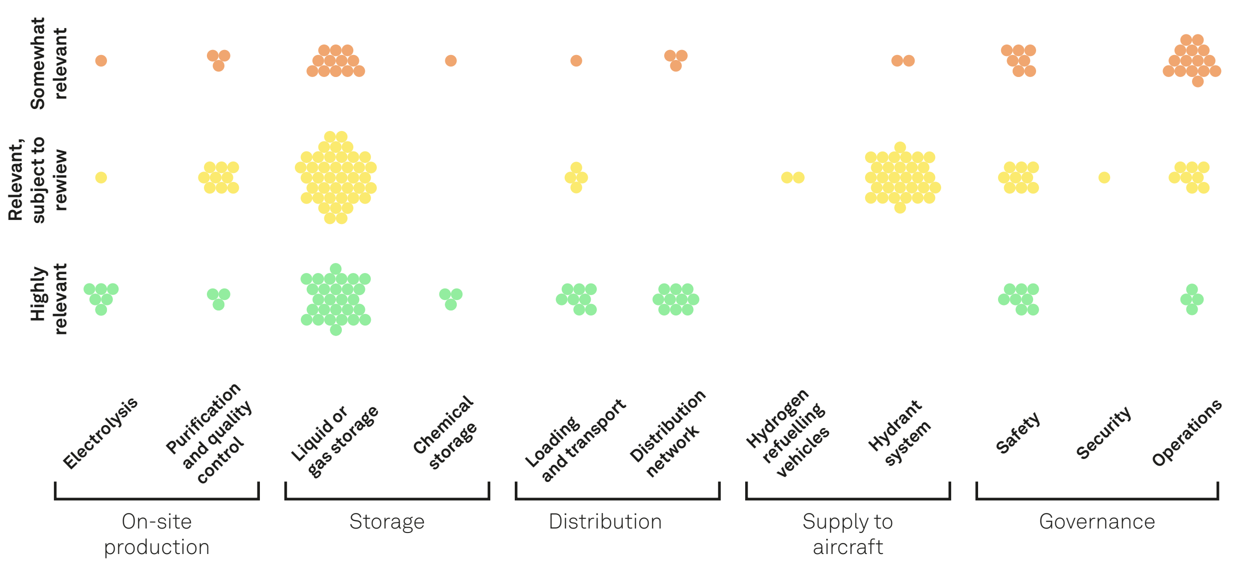
Figure 8: Number of standards within each supply chain stage and sub-area of focus – hydrogen

To interact with the tree map:

- Click on a sub-area of focus within a supply chain stage (e.g. "Liquid or gas storage").
- Hover over any standard to view the associated details of that standard.
- Use the dropdown menu to filter the data by relevancy classification.

"Liquid or gas storage" accounts for more standards than any other sub-area of focus (81), while no standards of relevance were identified for "Gasification", "Liquefaction", and "Fuel swapping".

Figure 9: Mapping standards map across each sub-area of focus – hydrogen



To interact with the survey map:

- Assign the following settings: Group by "sub-area of focus", Shade by "relevancy", Compare "relevancy".
- Hover over any dot to view the associated details of that standard.

There appears to be excellent coverage of highly relevant standards for "Liquid or gas storage", with promising coverage across most other sub-areas of focus too. However, the map shows significant gaps associated with "Hydrogen refuelling vehicles" and "Security", which would require further investigation to understand fully.

Standards by origin

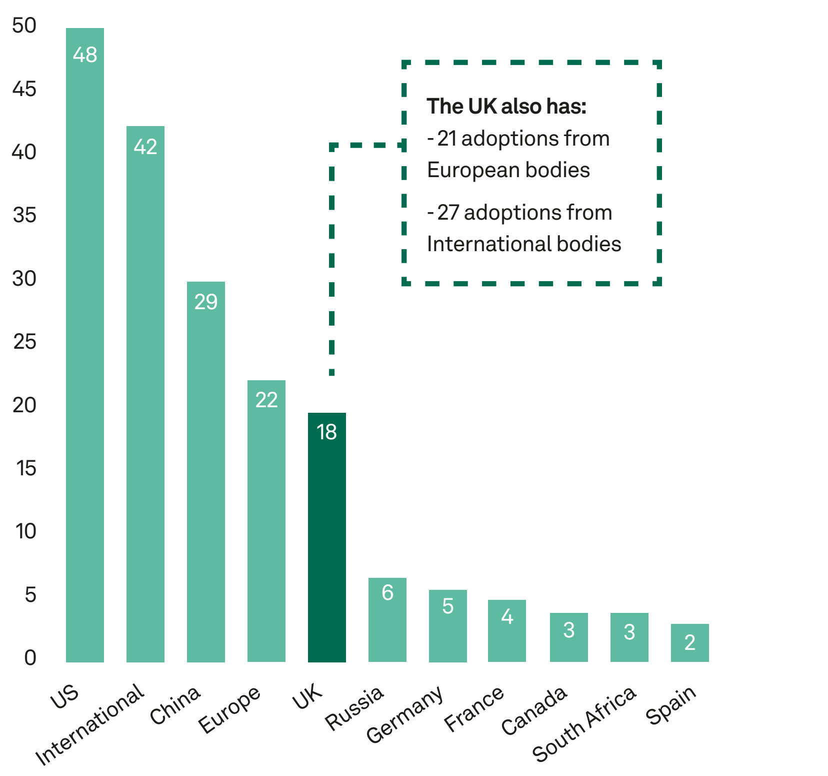


Figure 10: Number of standards by country/region of origin – hydrogen

The UK has developed 10% of relevant standards related to hydrogen technology, compared to significantly higher output from the US (25%), the International community (22%), and China (15%). However, as a member of CEN and CENELEC, BSI is obliged to adopt all European (EN) standards and chooses to adopt many of the International (ISO and IEC) standards.

In addition, BSI sits on International and European committees and provides British expertise in this space. A full analysis of the findings is available in Annex A which details the number of standards that BSI has influenced and adopted from European and International standards bodies.

A total of 49 different committees were identified, of which the top 10 account for 64% of the 189 standards in the final dataset. This is a much higher concentration compared to the findings for electric power), which may be indicative of the relative immaturity of the hydrogen fuel infrastructure industry

Presentation of findings - Electric

Standards classified by relevancy

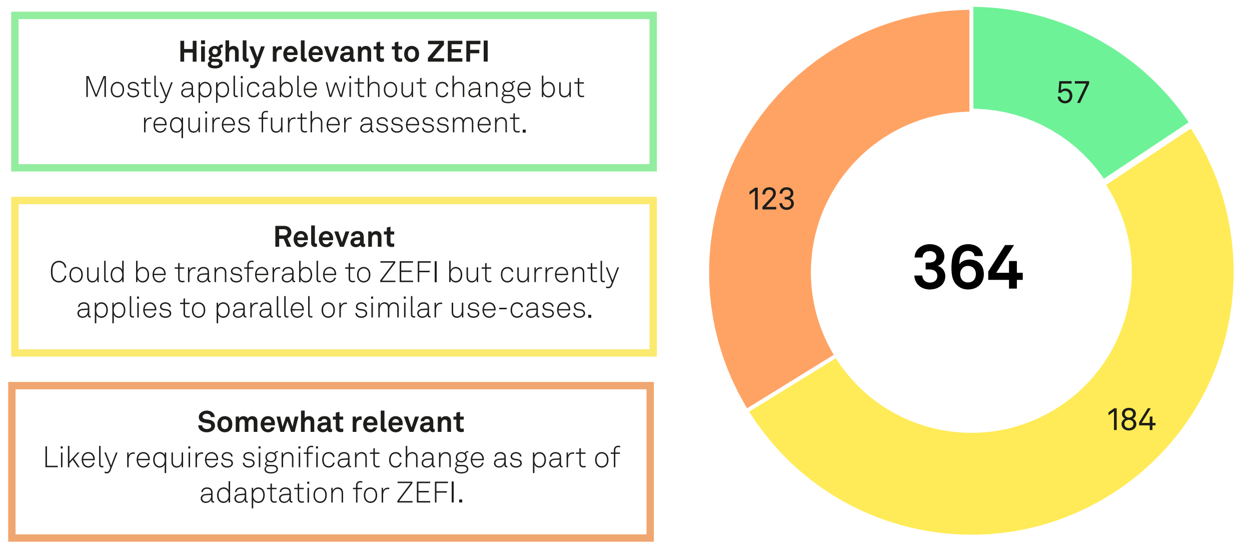


Figure 11: Standards classified by relevancy – electric

A total of 364 unique relevant standards were identified across the ZEFI standards landscape for electric power, 57 (16%) of which being highly relevant in their current form.

A total of 52 standards were returned more than once, as they applied across multiple supply chain stages or sub-areas of focus. The frequency with which a standard appears and overlaps across the results is an indication of how specific or wide-ranging it may be.

Those which occurred three times - more than any others - are:

- AfK 8, "Cathodic protection against corrosion for steel pipes of high-voltage cables".
- GB/T 37293, "Urban public facilities - Specification for operation management and service of electric vehicle charging/battery swap infrastructure".
- GB/T 37295, "Urban public facilities -Requirements for security and protection system of electric vehicle charging/battery swap infrastructure".

It is worth reiterating that the potential breadth of these standards may not necessarily translate into importance for ZEFI.

Standards landscape overview

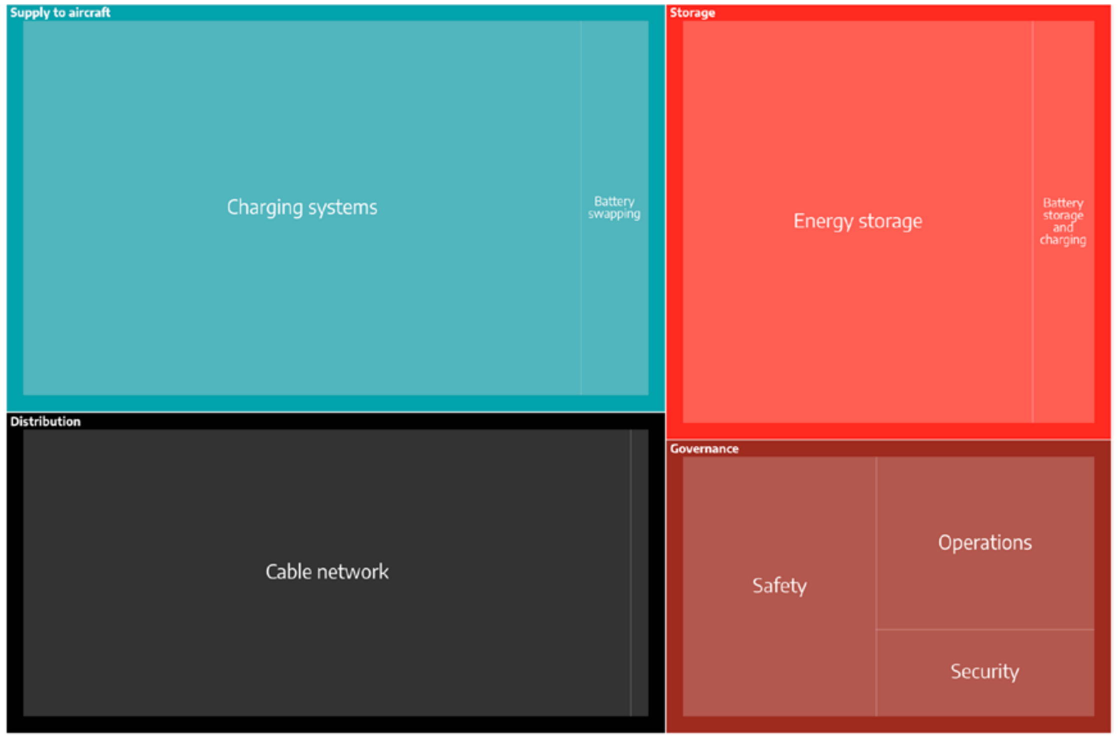


Figure 12: Number of standards within each supply chain stage and sub-area of focus – electric

To interact with the tree map:

- Click on a sub-area of focus within a supply chain stage (e.g. "Battery swapping").
- Hover over any standard to view the associated details of that standard.
- Use the dropdown menu to filter the data by relevancy classification.

Standards associated with "Charging systems" account for more than any other sub-area of focus (125), while only three standards of relevance were identified for "Battery transport" under the "Distribution" part of the supply chain.

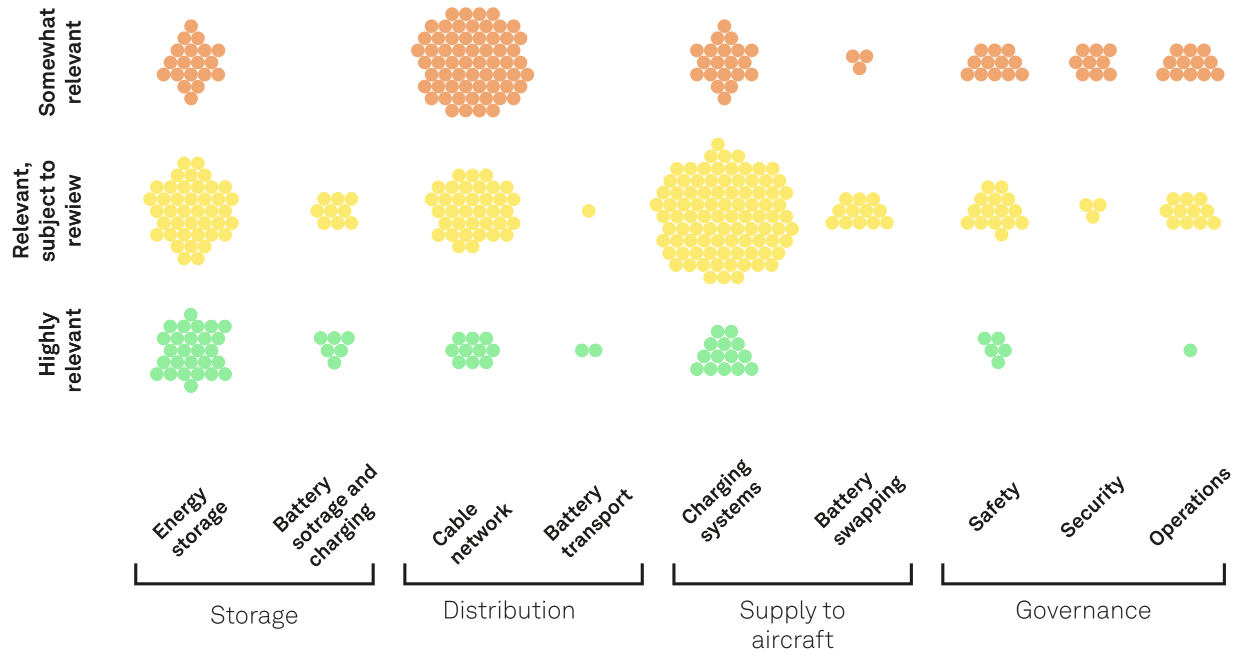


Figure 13: Mapping standards map across each sub-area of focus– electric

To interact with the survey map:

- Assign the following settings: Group by "sub-area of focus", Shade by "relevancy", Compare "relevancy".
- Hover over any dot to view the associated details of that standard.

There appears to be excellent coverage of highly relevant standards for many sub-areas of focus including "Energy storage", "Cable network", and "Charging systems". However, the map shows potentially significant gaps associated with "Battery transport", "Battery swapping" and "Security", which would require further investigation to understand fully.

Standards by origin

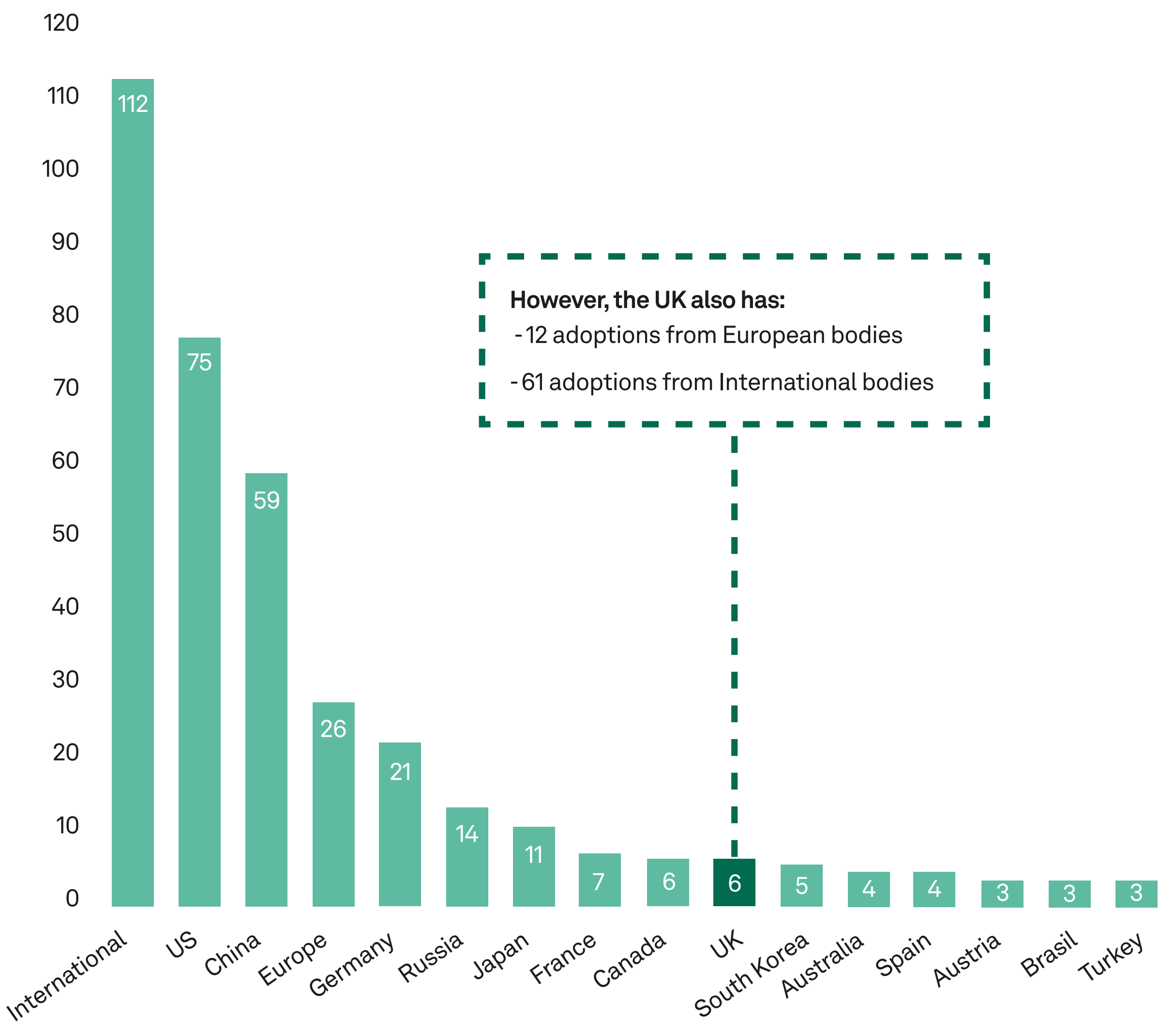


Figure 14: Number of standards by country/region of origin – electric

The UK has developed 2% of relevant standards related to electric technology, compared to significantly higher output from the International community (31%), the US (21%), and China (16%). However, as a member of CEN and CENELEC, BSI is obliged to adopt all European (EN) standards and chooses to adopt many of the International (ISO and IEC) standards.

In addition, BSI sits on International and European committees and provides British expertise in this space. A full analysis of the findings is available in Annex A which details the number of standards that BSI has influenced and adopted from European and International standards bodies.

A total of 95 different committees were identified, of which the top 15 account for 57% of the 364 standards in the final dataset. This is a much lower concentration compared to the findings for hydrogen power, which may be expected given the relative maturity of the electric infrastructure industry compared with hydrogen fuel infrastructure.

7 TRIG:ZEF and Demonstrator Interviews

Purpose of interviews

Four exploratory, in-depth interviews were conducted with Transport Research Innovation Grant winners (TRIG) and demonstrators to fulfil the following objectives:

1) To gather the learnings from the trial and demonstration activities

2) To ascertain the industry challenges with existing standards

3) To identify the key areas with standards gaps and the opportunities for new standards.

Sample

The participants were specifically selected to ensure a diverse range of views were captured; we chose a mix of Technology Readiness Level (TRL) and their project focus areas covered both hydrogen and electric.

They fell into the following categories:

Organization Name	Profile	TRL	TRL Description	Project Focus
HIVE Composites	TRIG triallist	2-5	Supporting early research & development	Hydrogen composite pipework
Warwick University	TRIG triallist	2-5	Supporting early research & development	Modelling of hydrogen explosive risk
ZeroAvia	TRIG triallist	2-5	Supporting early research & development	Liquid hydrogen feasibility study
Zeroavia	Demonstrator	6-9	Demonstrating UK capabilities for ZEFI	Safety requirements of gaseous hydrogen
NeboAir and Nuncats	Demonstrator	6-9	Demonstrating UK capabilities for ZEFI	Electric light aircraft and solar chargers

Note:
Due to the low sample size the findings are indicative only.

General findings

Overall, the trials and demonstrations are going well and will complete on schedule.

The interview findings corroborate the quantitative findings from the standards landscape, specifically in areas like gaseous hydrogen, standards do exist but they are not very mature and in addition they are not specifically tailored to the airport environment. Therefore, participants are using existing standards where they exist and adapting them to their individual requirements.

The main area where there is a complete lack of standards is liquid hydrogen.

Within the electric infrastructure, there is a greater volume of existing and applicable standards. The core issue is the absence of an extensive infrastructure, e.g. three-phase supply of green electricity.

Future standards requirements:

Hydrogen

Stakeholders interviewed expressed a need for general governance around the applicability of hydrogen within the airport environment.

Specific areas identified by participants that would need to be considered are:

- **Safety zones** - airports will need to operate with strict safety zones to mitigate against the explosive properties of hydrogen. For example, calculating how far the refuel site needs to be away from the passengers and the workforce etc. Zones also need to consider leaks; their containment and management of hydrogen leaks or pooling in voids of buildings/ceiling corners etc.
  Standardization will be required for airport layout for new airport developments in relation to dual fuel (hydrogen and electric) and jet fuel and SAF.
  The zones will need to allow for:
    - Storage spheres - (Note: including considering COMAH regulations)
    - Liquefier - to liquefy the hydrogen
    - Electrolyzer - depends where you produce the hydrogen (on-site by steam or wind turbines)
    - Airplanes some hydrogen, some fuelled by battery
- **Calculations for liquid hydrogen spills** - there are generic calculations but these need to be specific to airports - and by specific hazards, as every application is different.
- **Dispersion calculations** - the participant has been looking at the dispersion of 10 tonnes of liquid hydrogen, in different weather conditions and in different situations. The calculations need to be done with specific airport scenarios in mind.
- **Co-existing fuel scenarios** - hydrogen storage and refill with conventional jet fuels as well as battery-charging facilities. Ignition sources would be unavoidable.
- **Composite pipes for hydrogen** - there are existing standards in composite pipes within the oil and gas industry but these need re-working to allow for hydrogen specifics, eg. hydrogen permeability, leaks and embrittlement. Incorporating elements like sensors, liner materials, end fitting materials, tensile tests for the tape etc.
- **Safety re underground pipelines** - what are the safety considerations that people need to consider when putting down underground pipelines for hydrogen in the airport.
- **Standardise fuel delivery into an airport** - how does the delivery work, what are the safety standards required, ie. 'make sure there's always x amount of gap between inlet and storage' or 'the storage pressure must be x'
- **Refuelling communication protocols for commercials** - possible adaptation of existing standards for calibrated pumps to ensure commercial accountability of how much hydrogen is being pumped in.
- **Electrolysers** - electrolyser standards exist but they will need adapting in terms of safety to allow for more pragmatic and practical approaches.
- **Purity reduction** - The current high specification for hydrogen purity for fuel cell use (99.999% purity) may hinder practical applications due to the cost and quality management implications.
- **Mitigation measures** -
    - **High pressured pipes** - Mitigation measures need to be considered regarding the congestion of pipes and the potential problems with spills, ie. liquid hydrogen interacting with the tarmac would form a highly explosive cloud with powders.
    - **Storage** - measures to control the explosion of storage tanks to contain the blast or fire getting into nearby equipment.

Electric

Electric aircrafts are operational in the UK, and the required infrastructure technology is more advanced than hydrogen within the airport scenarios. The core challenge is the charging infrastructure. Regional airfields need to be equipped with the three-phase electricity as standard to create a linked-up infrastructure.

The two core elements identified as requiring future standards are:

- **Framework for airport operating procedures** - not just in-air but there needs to be a focus on-ground traffic management, e.g.
    - How to charge the aircraft
    - How to check that the aircraft is communicating to the charger
    - How to connect the charger to the aircraft the charger
    - Can it be refuelled during/in rain/wet weather etc.

- **Physical infrastructure** - investment required ensuring all airfields have moved towards an ethical and 'green' three-phase electricity available
    - Although solar chargers are well tested, the hours of sunlight in a UK winter are limited. Until solar cell technology improves, application of solar power in this use case is a limiting factor.
    - Wind turbines are restricted on smaller airfields; the height of the poles is a risk for light aircraft, as is the vortex effect created by the turbine blades.

8 Standards gaps & requirements Qualitative analysis

Building upon the standards searches and data from the quantitative analysis, the qualitative analysis used this data to assess the extent that ZEFI objectives are covered by existing standards and identify areas in need of future standards development activities.

This was combined with industry insights captured in workshops to develop a set of hypotheses regarding the standards gaps. The validation workshop considered a justification for prioritisation as set out in Section11. of this report and further explored sub areas of focus for each technology area. This included 8 priority sub areas of focus from a total of 23 sub areas of focus based on the gaps identified in the quantitative analysis to be validated as part of the workshop

From the insight gained at the workshop, the choice of prioritisation was further refined to confirm 6 sub areas of focus in total that were validated as having significant gaps in standards. However not all of these are considered a priority for standardisation development, as some of areas are linked to longer term capabilities development expected from the operating concept as detailed in Section 10 below. For example, battery swapping is identified as red (no relevant standards identified), whereas fixed charging is identified as yellow (relevant standards subject to review). However, despite battery swapping being red, work on standards relating to fixed charging capabilities at airports has been given a higher priority, as without their provision, the minimum infrastructure cannot be provided. Whereas battery swapping is a longer-

Relevancy rating

Green	Highly relevant to ZEFI. Mostly applicable without change but does require further assessment.
Yellow	Relevant, subject to review. Could be transferable to ZEFI but currently applies to parallel or similar use-cases, e.g. automotive, mainstream fuels, general infrastructure.
Amber	Somewhat relevant. Likely requires significant change as part of adaptation for ZEFI, e.g. niche use-cases which apply to other fuels, modes of transport, or closely-related equipment.
Red	No relevant standards identified

9.1 Hydrogen

Parent area	Sub-area coverage	Summary coverage hypothesis
On site production	Electrolysis	There are existing standards for electrolysis e.g. ISO 22734 however this standard is relevant to industrial, commercial and residential applications and would need to be adapted to suit the airport environment.
	Gasification	There are standards that are under development for gasification (i.e. ISO/AWI 23898) however these would require adaptation for the airport environment.
	Purification and quality control	There is a gap in aviation hydrogen quality and purity specifications. There are standards from other sectors (e.g. road transportation) that might be adapted on the basis of aircraft requirements. However, hydrogen quality standard development should be linked to the aircraft fuel cell or combustion requirements. The requirements of gaseous and liquid hydrogen should be differentiated depending upon the specifications within a standard or two separate standards should be developed: covering gaseous hydrogen quality requirements for fuel cell and combustion and liquid hydrogen quality requirements for fuel cell and combustion.
Storage	Liquefaction	There were no standards identified in this area however given the process is adopted in other industries. There are customised standard operating procedures in use by oil and gas industries which could be explored further.
	Liquid or gas storage	There are existing standards for storing hydrogen, however no standards for storing the hydrogen in liquid / Gaseous form within the airport boundary. Other industries (petrochemicals, airspace, road transport) best practice and standards wherever possible should be adapted for aviation.
	Chemical storage	Chemical storage is a new concept and the technology is currently being developed, hence there is a limited number of standards that were identified covering basics of the chemical process. No standards were identified that cover the chemical storage within the airport boundary or use of the chemically stored hydrogen within the airport.

Parent area	Sub-area coverage	Summary coverage hypothesis
Distribution	Loading and transport	Hydrogen transportation standards exist in other industries. However, more information is needed to understand the temperature and pressure parameters these standards cover in order to load and transport hydrogen to the apron (e.g. refuelling vehicles, loading of hydrogen from airport storage and delivery to the aircraft using the hydrogen refueller).
	Hydrant network	There are existing standards for hydrogen fuelling for road transport but there is a significant gap in airport hydrant network application related standards. Hydrogen pipeline standards also exist for delivery to the point of use/storage. For airport hydrogen hydrant pipeline standards do not exist. This system would be required to tackle large quantities uplift for long haul flights considering required turnaround times.
Supply to aircraft	Hydrogen refu-elling vehicles	No relevant standards were identified in this area as hydrogen refuelling vehicles are not yet developed. Standards should focus on the refuelling rate and maintaining the required properties of hydrogen, Metering, safety interlocks etc. during the supply to aircraft.
	Hydrant dispenser	Hydrogen Hydrant dispenser vehicles are not manufactured yet and therefore there are no existing standards. There are standards for the existing hydrant dispenser but they are yet to be developed for hydrogen dispensing to meet the requirements of high pressure, low temperature refuelling
	Fuel swapping	No standards were identified relating to fuel swapping due to the early stages of the technology concept within the aviation sector.
Governance	Safety	There are safety standards covering stationary equipment and hydrogen fuel cell road vehicle applications. Standards for safety relief valves, pressure relief valves, H2 instrumentation require adaptation based on aviation industry operating parameters. The use of material data safety sheets (MSDS), quality certificates (COQ) and risk management need to be considered to support development of safe operating procedures.

Parent area	Sub-area coverage	Summary coverage hypothesis
	Security	There are AVSEC standards and local airport standards existing for securing the current fuels products along with the requirements for access and egress of any transportation that need to be adapted for the hydrogen.
	Operations	There are standard operating procedures in upstream production but there is a need to develop standards for specific operations relating to aviation fuel supply e.g. loading, sampling, refuelling etc. Standards should account for automation of some (or all) operations at the airport.

9.2 Electric

Parent area	Sub-area coverage	Summary coverage hypothesis
Storage	Energy storage Battery storage and charging	Standards for energy storage, battery storage (systems) and charging are available from other industries/ domains for battery storage utilised by District Network Operators (DNOs). These standards may be used for airport operations; however an in-depth assessment is required considering stringent safety and operations of airports.
Distribution	Cable network	There were no standards identified in this area however given the process is adopted in other industries. There are customised standard operating procedures in use by oil and gas industries which could be explored further.
	Battery transport	There are few battery transport standards for electric road vehicles but nothing available for the aircraft domain. New standards will be required to move batteries for the airports taking safety and traffic management aspects into consideration. Moving battery can be a priority for the small airports, not many specific battery transport/mobile battery charging standards for airports are currently available.

Parent area	Sub-area coverage	Summary coverage hypothesis
Supply to aircraft	Fixed charging	Charger Standards from the Electric Road Vehicle charging may be used/adapted but require consideration relating to plugs, socket and charging communication protocols etc. that are compatible with requirements of aircraft. Deep dive into EV road vehicle standards will be good step for aviation industry to investigate bidirectional charging, V2G comms, sockets and connections at aircraft side/apron. These standards can be used/ adapted for battery charging at airports taking safety and operation issues into consideration
	Battery swapping	No standards were identified in this area as battery swapping is a new concept within the aviation sector.
Governance	Safety	There are safety standards for battery swapping / charging assemblies and installation stations in hazardous environments which need to be reviewed to consider adaptations for the requirements of the airport environment.
	Security	There are existing standards for securing electrical transformers (501kva or higher), cables, conduits, communications etc. however these need adaptations to suit ZEFI applications.
	Operations	Safety management needs to be updated individually by the airports based on their requirements and resources available taking into consideration safety and operational standards/practices for the airports. Further feasibility studies required for operational standards to confirm based on aircraft type, location, space etc. All stakeholder needs to come together to agree on international standards for operations. Potential resistance to change, different application of technology or use of new tech., need to understand the operational demands accordingly for management of change. Ground Power Units (GPU) and Auxiliary Power Units (APU) are already being connected to aircraft to provide minimal power during the operation of embarkation and disembarkation eg. running the Air Conditioning, lights, cockpit etc. Current operation and safety standards can be used but may need updating as power supplied for charging infrastructure will be a higher rating.

9 Developing the capabilities

In order to draw conclusions and support recommendations for future standards development - this report considers the outputs of the research areas against three separate considerations based on industry insight and aligned work undertaken by CPC to support the zero emission flight infrastructure agenda:

A. What are the observable gaps - based on quantitative analysis of the landscape review (Section 6) and qualitative hypothesis statements of what the industry/technology needs (Section 9).

B. What are the prioritised need for standards to support ZEFI. Based on technical insight of what needs to be developed first.

C. Consideration of capability levels of airports.

Criteria A and B were presented and considered as part of the scoping and validation workshop along with opportunity to bring a correlated insight from the structured interviews of lower TRL TRIG project participants and more mature TRL project demonstrators.

Criteria C draws on the Blueprint for Zero Emission Flight Infrastructure that sets out a number of interventions required within the UK to facilitate and enable the rapid advancement of the net zero aviation infrastructure. In essence it presents a systems view of the emerging net zero aviation infrastructure setting out expectations for functional capacity and a maturity framework for capability that airports can aspire/develop to as out of a investment in strategic assets for this agenda. These capability levels were developed through a series of stakeholder engagement activities that looked at considerations such as personnel and skills, commercial implications, physical/site constraints, regulations and policy.

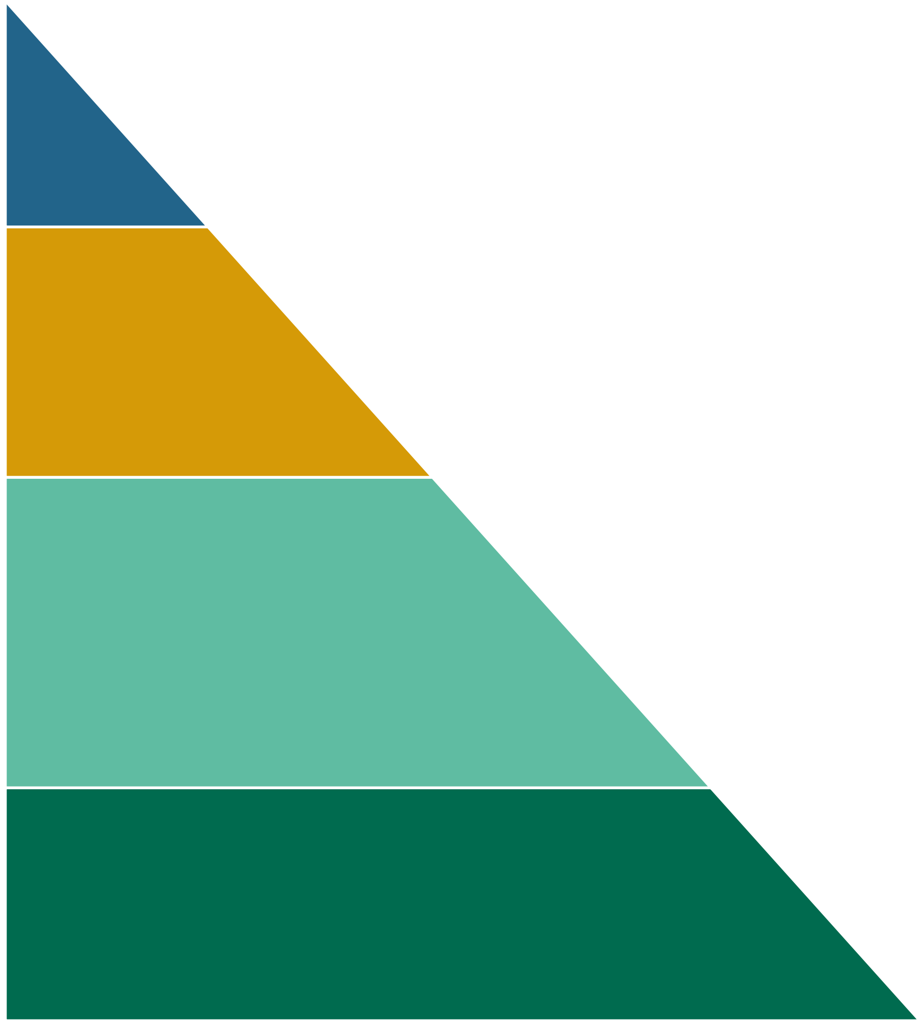
A series of capability levels enable airports to plan for the transition towards hydrogen and electric aviation. The four levels are:

LEVEL 1 – Basic handling and safety capability

LEVEL 2 – Light-touch capability

LEVEL 3 – Comprehensive capability

LEVEL 4 – Advanced capability

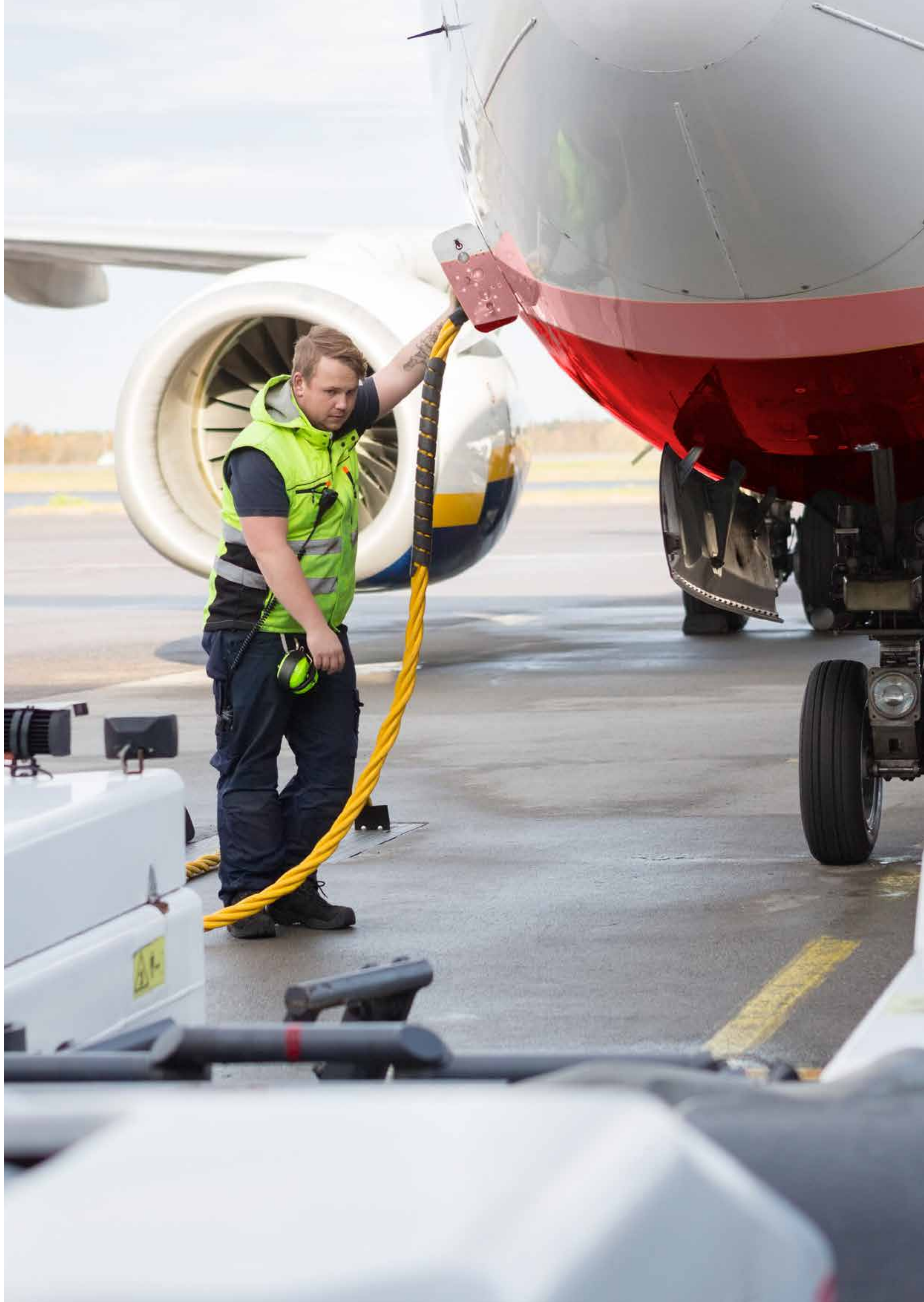


Level 1 - **Basic handling and safety capability**: The airport can safely handle an aircraft but does not usually have fuel availability on site.(e.g., diversion, emergency operation, early demonstrator or there and back short routes). Safety equipment and procedures are in place to handle electric and hydrogen aircraft. A standby fuel or charging equipment supplier should be identified to cover such operations.

Level 2 - **Light-touch capability**: Basic aircraft handling where hydrogen is supplied from an off-site store and electric charging is within the aircraft only. There may be limitations on the volume of aircraft and slots that can be handled.

Level 3 - Comprehensive capability: Introduction of on-site storage for hydrogen and fixed electric charging infrastructure.

Level 4 - Advanced capability: Introduction of on-site hydrant distribution for hydrogen and electric battery swap technologies. A small airport may only reach a lower capability level as needed for their operations, whereas a larger airport is likely to progress through the levels as they scale up. Financial support, incentivisation and prioritisation for innovation can be aligned with these capability levels.



10 Prioritisation of standards requirements

Combining the findings together has identified a significant number of gaps in standards across aviation fuel supply chain stages that will need standards to be developed or adapted to support zero emission flight.

Given the resource and time requirement to enable this standardisation activity, it is important to prioritise the activities that are of an immediate priority, compared to topics that are more of a longer-term objective. This is to ensure that high priorities can be taken forward to allow airports to start to develop the required capabilities, whilst also having a longer-term view of the additional capabilities that are required and the standards associated with these capabilities that need to be developed.

11.1 Prioritisation criteria

A set of prioritisation criteria have been developed as a means of defining the priority for standards development activity. These criteria consider the type of standards that will be most essential for enabling zero emission flight capabilities. Standards that support the minimum capabilities required for zero emission flight are given a high priority with lower priority given to infrastructure such as:

- Infrastructure not immediately required, due to the ability to manage via alternative solutions e.g., on-site production, hydrogen storage
- Infrastructure that is at a low TRL which is therefore not at a mature enough stage for standardisation e.g., battery swap, fuel cell swap

Standardisation priorities	Description	Capability levels supported
Priority 1	Priority 1 standards will be required to support minimum handling and safety capabilities along with light touch Zero Emission Flight capabilities (Capability levels 1 and 2) for the operation of aviation fuel supply / charging of an aircraft. There may be limitations on the volume of aircraft and slots that can be handled.	Standards required to support Capability Level 1: minimum handling and safety capabilities and Capability level 2: Light-touch capabilities
Priority 2	Priority 2 standards will need to be in place to provide more comprehensive capabilities (Capability level 3: comprehensive capabilities). These standards are not top priority as operations can be managed via alternative solutions.	Standards required to support Capability level 3: comprehensive capabilities
Priority 3	Priority 3 standards will be needed for more advanced capabilities (Capability level 4: advanced capability) to ensure provision of more flexible/resilient infrastructure for much higher demands. These standards are the lowest priority as the infrastructure they support depends upon various other parameters i.e. space, technology development & operational requirements such as volume and type of aircraft.	Standards required to support Capability level 4: advanced capabilities

11.2 Standardisation priorities - Hydrogen

Area of focus	Why the need to prioritise	Priority Level
Arrival at Site	Production of hydrogen as per the required parameters and standards is essential. Properties of the hydrogen fuel must be maintained upstream and downstream of the supply chain. This is the required ancillary infrastructure to be in place prior to any other stages.	Priority 1
Storage and Management	The hydrogen fuel can be bridged from the refinery via trucks and supplied to the aircraft.	Priority 2
Distribution to apron -Hydrant Pipeline	Due to space limitations at the airport this could be a challenge and would require appropriate infrastructure for hydrogen transportation.	Priority 3
- Refueller	To refuel an aircraft, it is very critical to have the right equipment in place.	Priority 1
Supply to aircraft	Properties of the fuel need to remain unchanged during the supply to aircraft.	Priority 1
Governance - Operations - Safety - Security	Operational procedures will be needed to define procedures for refuelling aircraft to ensure safe and secure installation, operations and maintenance of hydrogen and electrical infrastructures.	Priority 1

11.3 Standardisation priorities - Electrical

Supply chain stage	Why the need to prioritise	Priority Level
Storage and Management - Energy Storage	Energy/Battery storage facilities at the airport for storage of energy for the charging infrastructure can be utilised when surplus energy is available from the onsite generation or when electricity costs are lower. It can work as a buffer for supply and demand changes.	Priority 2
Battery storage and charging	Charging and storage facility at the airport for charging the battery modules used for battery swapping. Battery swapping is a longer-term objective and development of standards is subject to technology maturity.	Priority 3
Distribution to apron - Cable networkt	Cable network is a high priority to provide enabling infrastructure. It should be appropriate for expected demands of various systems including charging infrastructure and co-existing with airport operations.	Priority 1
Distribution to apron -Hydrant Pipeline	Due to space limitations at the airport this could be a challenge and would require appropriate infrastructure for hydrogen transportation.	Priority 3
Supply to aircraft - Fixed charger	Fixed charger infrastructure providing tens of kilowatts to megawatt power capacity for the aircraft charging is a high priority to provide the enabling infrastructure.	Priority 1
- Mobile charger	Mobile charging infrastructure is needed for charging the aircraft where fixed charging infrastructure is not available or a viable option. Mobile charging consists of a transporting vehicle with on-board battery electric storage. Alternative on-board energy storage options could be considered such as hydrogen fuel cells.	Priority 1
Governance - Operations - Safety - Security	Operational procedures will be needed to define procedures for charging aircraft to ensure safe and secure installation, operations and maintenance of electrical infrastructures.	Priority 1

11 Recommendations

To support and accelerate the progress of the Zero Emission Flight Infrastructure (ZEFI) agenda; this research highlights the need for 5 interlinked standardisation activities.

These are aligned to pillars of intervention (shown below) and collaboratively support the establishment of a net zero emission flight infrastructure; the progression of the ZEFI 'operating concept model' and enable the phasing out of fossil-fuelled aircraft,

Figure 15: Blueprint for zero emission flight infrastructure, Connected Places Catapult

The future standardisation activities proposed below are over short, medium and long-term timelines. We highly recommend the short-term activities should be commenced immediately and developed in parallel with UK demonstrators, as this will enable knowledge generated from demonstrators to inform immediate standards creation and development of the longer-term standards roadmap for ZEFI.

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Stage	Timescale*	Activities
1. Enabling future standards	Short term (1 year)	• Developing an aviation standards community for ZEFI • Defining overarching principles and outcomes for ZEFI standards • Prioritising future standards work • Developing a long-term standards roadmap • Establishing ZEFI standards steering group • Establish ZEFI strategic programme advisory group
2. Defining future standards	Short term (1 year)	• Assessing feasibility of how existing standards might be adapted from other industries • Defining/wireframing core operational principles and design/ performance specifications • Support and align with aviation regulatory environment for ZEFI • Defining proposals and justification for future standards development work
31. Mobilising standards development	Medium term	Commence standards development for Hydrogen including: • Quality and purity specifications • Foundational guidance to support capability level 1 • Refuellers and dispenser vehicle standardisation • Storage and management • Governance requirements and arrangements for operations, safety and security Commence standards development for Electric including: • Supply to aircraft • Governance requirements and arrangements for operations, safety and security
4. Adapting standards for ZEFI	Medium term	Adapting existing Hydrogen standards for ZEFI including • liquefaction standing instructions / local procedures • establishing working groups to consider future requirements Adapting electric standards for ZEFI including: • Energy storage • Battery storage • Distribution • Governance requirements and arrangements for operations, safety and security • Alignment with work in Faraday battery challenge

Stage	Timescale*	Activities
5. Developing forward programme	Long term	Developing the longer-term strategy and roadmap including considering: • Evaluating and reviewing progress • Horizon scanning and landscape review to consider emerging work • Tracking technology development and aligning need for stand-ards • Signposting and awareness raising • Support for implementation • Engagement with regulators

The following provides a more detailed description of these standards activities. All five areas are interlinked and can be managed conterminously.

1. Enabling future standards: (Initiation 0-12 months) an aviation standards community and programme should be established around Zero Emission Flight Infrastructure (and possible related topics). This first step could include the following:

- Define **overarching principles and outcomes** for ZEFI related standards, to ensure they meet aviation sector needs, enable the required capabilities and support desirable market outcomes including sustainability, interoperability, open market access and safe operations
- Support **prioritisation of future standards work** including the structure, membership and work programme of committees and tasks groups
- Initiate development of a **long-term standards roadmap** to support a safe and successful adoption of ZEFI and ensuring this roadmap remains relevant as the operating concept evolves
- Establish a ZEFI **standards steering group** or equivalent committee structure, to ensure standards activity and outputs are aligned with the overarching principles, outcomes of the operating concept and formal standardization through relevant bodies.
- A ZEFI **strategic programme advisory group** may also be needed to assess the regulatory context and governance of future standards work in promoting alignment and fit with policy aims.

2. Defining future standards: (Short term 0 - 18 months) An initial discovery project should be carried out to build on the findings from the standards landscape and gap analysis. This discovery should include technical analysis on key standards priorities and defining how to deliver on these priorities. It is not foreseen that this work would result in the creation of any new standards, however it could aim to provide the best foundations for future standards development. This may include:

- Undertaking technical feasibility studies, industry hackathons and other analyses to **determine how existing standards from other industries, might be adapted** for the purposes of ZEFI
- Carrying out technical analysis of specific areas where there are gaps in standards (e.g. Megawatt charging) to **start defining/wireframing core operational principles and design/performance specifications** with relevant authorities and the ZEFI standards community, for further testing and analysis.
- Undertaking work to understand how the standards programme would **support and align with the aviation regulatory environment for ZEFI**, working with regulators and other interested parties including the incentives for adopting standards as required
- Defining **proposals and justification for future standards development or related work** (e.g. business case evaluation)

3. Mobilising standards development: (Short to Medium Term 9 – 24 months) new standards development: Based on the findings from stage 2 (definition) commence standards development activity should be prioritised to help accelerate ZEFI infrastructure ensuring that the programme is developed to ensure core infrastructure and operational safety needs are met for ZEFI deployment within airport environment. This should be aligned with the principles and outcomes defined in stage 1 (enabling) and based on the research priorities for standards and prioritised in the technology areas below:

For hydrogen:

- **Arrival at site** - Developing standards to ensure the quality and purity specification of hydrogen /liquid hydrogen to the required parameters can be assessed and monitored upstream and downstream through the airport infrastructure.
- Developing standards and or guidance to assess what is required for the ancillary hydrogen infrastructure to meet the prerequisite functional capability of Level 1 airport and to act as foundation for subsequent airport capability levels.
- **Refueller and supply to aircraft** - Developing standards to ensure the provision of refuellers and dispenser vehicles and which can assess operational and delivery parameters and dispense on-spec fuel to aircraft.
- Storage and management - Assess existing standards on the liquefaction of hydrogen in other industries in order to develop technical and operational requirements for the liquefaction of hydrogen as part of fuel supply at an airport site. Develop standards to address the storage of hydrogen in pure or chemical form within an airport boundary.
- **Governance requirements and arrangements for operations, safety and security** - Operational procedures will be needed to define procedures for refuelling aircraft to ensure safe and secure installation, operations and maintenance of hydrogen and electrical infrastructures.

For electric:

- Supply to aircraft - Standards to govern the swapping of batteries to be used by aircraft. This is an emerging technology so standard development should be seen as an 'incubation process' where the requirements of standards align with developments in technology and the emerging infrastructure. This is a high operational priority.
- **Governance requirements and arrangements for operations, safety and security** - Operational procedures will be needed to define procedures for charging aircraft to ensure safe and secure operations and maintenance of charging infrastructures.

4. Adapting standards for ZEFI: (Medium to Long Term 12 – 48 months) Based on the analysis of existing standards potentially applicable to ZEFI, work with the relevant committees and standards development organisations responsible for these standards, to start adapting existing standards for ZEFI where deemed feasible.

For hydrogen:

- **Storage and management** - Adapt existing standards on the liquefaction of hydrogen in other industries in order to inform standards to govern the liquefaction of hydrogen as part of fuel supply at an airport site.
- Establish a working group to consider the future demands of standards for the hydrogen infrastructure including installation of hydrant System infrastructure at airports considering coterminous or parallel operations, safe operations and land use.

For electric:
Storage and management:

- **Energy storage** Adapting standards to govern Energy/Battery storage facilities at the airport for storage of energy for the charging infrastructure so that energy can be utilised when surplus energy is available from the onsite generation or when electricity costs are lower.
- **Battery storage**: Assess and align adaptation of existing standards on battery storage with insight and lessons learned from the Faraday Challenge (including requirements for battery boxes)
- **Distribution**: Battery Transport: Consider needs and adapt industry insight on best practice for moving batteries at airports taking safety and traffic management aspects into consideration - specifically noting sparsity of specific battery transport/mobile battery charging standards currently available for airports. This is a foundational and operational priority for the development of Level 1 capability airports.

Governance requirements and arrangements for operations, safety and security

- Operational procedures will be needed to define procedures for recharging aircraft to ensure safe and secure operations and maintenance of electrical infrastructures.
- Consider options to align resources with future Faraday Battery Challenge innovation work for future joined up standards development work so that these standards could apply to several industries and sectors.

5. Developing forward programme: (Long Term aligned to creation of a strategic programme), Undertake a review and assessment of the outcomes/success criteria for a ZEFI standards programme. This will support and inform future work, including the development/updating of a longer-term standards roadmap and supporting activities. This is best placed to be overseen within the scope of the ZEFI strategic programme advisory group. It will consider wider activities that might need to be undertaken (such as certification needs; internationalisation of UK-led standards; dissemination and training needs, etc) This will include:

- Horizon scanning and landscape review of industry bodies, working groups and relevant committees to recognise mutual interdependencies of this technology development and building links to aligned strategic standardisation road map programmes e.g. the Faraday Battery Challenge.
- Tracking technology development and aligning needs for standards development with emerging status of technology, policy development and emergence of regulations.
- Proactively signposting to raise awareness and enact the adoption of ZEFI standardisation as it emerges. This will include the marketing and promotion of standards development as part of ZEFI infrastructure adoption and promoting interoperability as part of wider standardisation support.
- Considering the role of standards as part of training and accreditation development to support long term implementation. This could include:
  - a planned cycle of dissemination highlighting existing standards, to increase awareness and encourage adoption.
  - Specific work on development and deployment of virtual and onsite masterclasses addressing the inclusion of standards in training, accreditation and certification as well as developing 'on site' capacity
  - Engagement with regulators and approved bodies to distinguish and differentiate between the standards required for the infrastructure and the regulatory approvals to support operations

This will allow for new/additional standards development opportunities to be identified, captured and addressed, whilst acknowledging wider dependencies, initiatives and technology development; across the economy and at both the national and the international level.

The report findings indicate that industry and infrastructure development are at the very start of this process with the short-term actions yet to begin. There is a potential 20+ standards that might need updating or developing across the technology areas, each of which even with prioritisation could take 12-18 months for national standard up to 3 years for international adoption through an ISO. A typical standards development process is presented in Annex D.

Therefore, there will be much work needed in parallel and at pace, but the critical work is getting the initiation and short-term work started so that foundations can be laid to mobilise this standards work. Aligned to the concurrent oversight of a standards road map strategy will ensure that technology, infrastructure and standards proceed hand in hand in the right way and mutually supports iterative development. The risk of not carrying out this work at this pace is that it would slow down the technology development and also result in products not having any formally recognised standards that would allow them to then become available on the UK market. The potential result of this is it would slow down the overall roadmap for zero emission flight infrastructure.

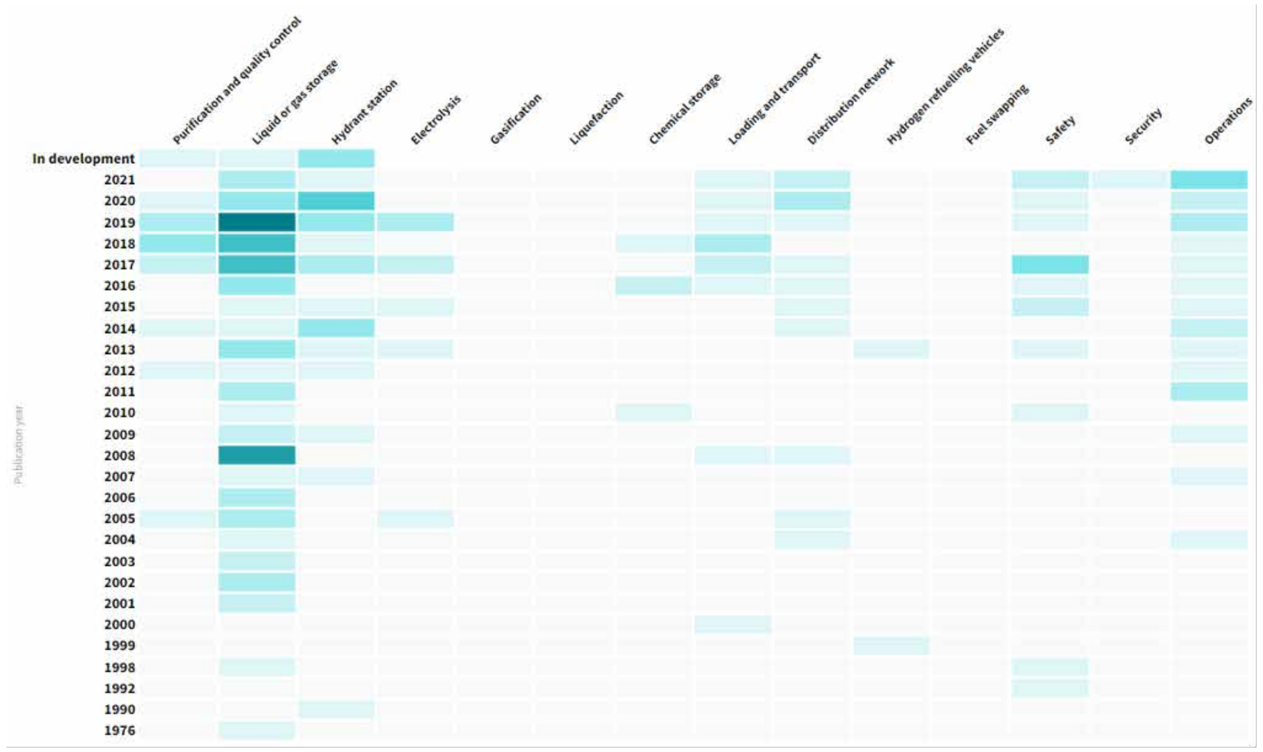
It should be noted that the ZEFI standards roadmap programme will need to be refreshed regularly (e.g. every 1-2 years) to ensure it remains relevant and can respond to the needs of industry, technology maturity, policy requirements and other external factors and lessons learnt.

12 Appendices

Annex A – Standards landscape results additional insights

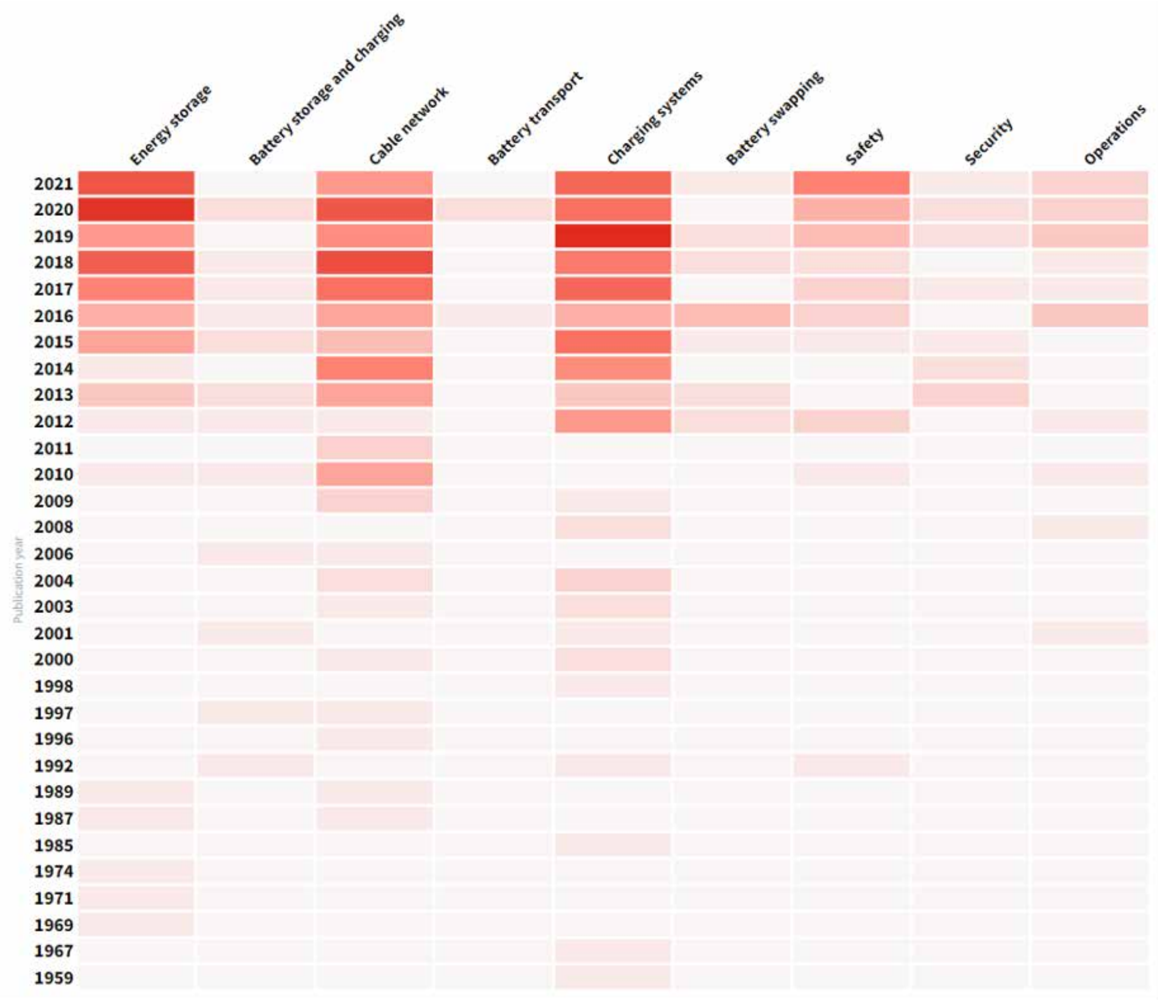
Age of standards based upon year: Hydrogen

The following presents a heatmap of standards based on age for hydrogen. This highlights that standards development activity for Hydrogen has been taking place largely since 2001 particularly relating to liquid and gas storage, with a number of standards developed in this area, compared to hydrant stations and standards relating to the distribution network, having more activity in more recent years since 2012, showing that there is a level of maturity in the development of standards for hydrogen as a sector



Age of standards based upon year: Electric

The following presents a heatmap of standards based on age for electric. This highlights that standards development activity for Electric has been taking place for a significant period of time including a number that date back to the late 1950s and 1960's however there has been a significant ramping up of activity since 2012, which can in part be attributed to the significant growth of electric vehicles market. However there are also areas with limited standards development history such as for battery transport and batter swapping which are new technology areas.



Annex B: Committees of interest

Hydrogen

INTERNATIONAL COMMITTEES	ISSUING BODY	BSI MIRROR COMMITTEES
CEN/TC 23 Transportable gas cylinders	CEN	**PVE/3** Gas Containers
CEN/TC 234 Gas infrastructure	CEN	**GSE/33** Gas Supply
CEN/TC 268 Cryogenic vessels	CEN	**PVE/18** Cryogenic Vessels
ISO/TC 158 Analysis of gases	ISO	**PTI/15** Natural Gas & Gas Analysis
ISO/TC 197 Hydrogen technologies	ISO	**PVE/3/8** Hydrogen technologies
ISO/TC 220 Cryogenic vessels	ISO	**PVE/18** Cryogenic Vessels
ISO/TC 58 Gas cylinders	ISO	**PVE/3** Gas Containers

Hydrogen

INTERNATIONAL COMMITTEES	ISSUING BODY	BSI MIRROR COMMITTEES
IEC/TC 69 Electric road vehicles and electric industrial trucks	IEC	**PEL/69** Electric Vehicles
IEC/TC 120 Electrical Energy Storage (EES) Systems	IEC	**ESL/120** Electrical Energy Storage
IEC/SC 22F Power electronics for electrical transmission and distribution systems	IEC	**PEL/22** Power electronics
ISO/TC 22 Road vehicles	ISO	**PEL/22** Power electronics
IEC/TC 20 Electric cables	IEC	**GEL/20** Electric Cables
IEC/SC 23H Industrial plugs and sock-et-outlets	IEC	**PEL/23/4** Protected Type Plugs & Sockets
IEC/TC 21 Secondary cells and batteries	IEC	**PEL/21** Secondary Cells & Batteries
IEC/TC 105 Fuel cell technologies	IEC	**GEL/105** Fuel Cell Technologies
IEC/SC 17C Assemblies	IEC	**PEL/17** Switchgear, Controlgear, & Hv-Lv
ISO/TC 20 Aircraft and space vehicles	ISO	**ACE/1** International and European Aerospace Policy and Processes
CLC/TC 21X Secondary cells and batteries	CENELEC	**PEL/21** Secondary Cells & Batteries

INTERNATIONAL COMMITTEES	ISSUING BODY	BSI MIRROR COMMITTEES
IEC/SC 8B Decentralized Electrical Energy Systems	IEC	**GEL/8** System aspects for electrical energy supply
IEC/TC 8 Systems aspects for electrical energy supply	IEC	**GEL/8** System aspects for electrical energy supply
CLC/TC 14 Power transformers	CENELEC	**PEL/14** Power Transformers

Annex C - Operational Concept Definitions

The following provides a set of definitions relating to the supply chain process stages as detailed in Figure 5 and Figure 6.

Technology	Sub-area of focus	Process definition statement
Hydrogen	Electrolysis	Production of hydrogen using water which passes through a solution and produces oxygen and hydrogen atoms. Reaction happens in an electrolyser. Commonly used electrolysis methods are Alkaline and Proto Exchange Membrane (PEM).
Hydrogen	Gasification	Gasification is the process of converting biomass- or fossil fuel-based carbonaceous materials into gases.
Hydrogen	Purification and quality control	Fuel cell needs pure hydrogen to operate. Hydrogen, when used as a fuel, quality needs to be checked during the transfer of hydrogen through the system. It involves sampling of hydrogen gas or liquid and testing it for presence of impurities, especially sulphur.
Hydrogen	Liquefaction	At an atmospheric pressure hydrogen has very volumetric density making it difficult to transport and store. In a liquid form hydrogen density is approx. 71kg/m3 while at atmospheric pressure its only 0.09g/m3. During liquefaction process hydrogen gas is compressed and cooled (using other gases) to a very low temperature of -253C to achieve lower volumetric density.
Hydrogen	Liquid or gas storage	Liquefied hydrogen is stored in the spherical shape insulated tank. Pressure and temperature is monitored and pressure is released through pressure release valve. Gas storage - Storage of hydrogen gas on site or near site in tanks designed to withstand high pressure. Hydrogen can be stored in various pressure ranges. Most commonly used pressures are 350bar, 700bar and high pressure of 1000bar. Tanks also need to withstand absorption of hydrogen that can lead to embrittlement of the tanks structure.
Hydrogen	Chemical storage	Chemical storage - Chemically bounded hydrogen is stored in the chemical storage container in solid or liquid form.

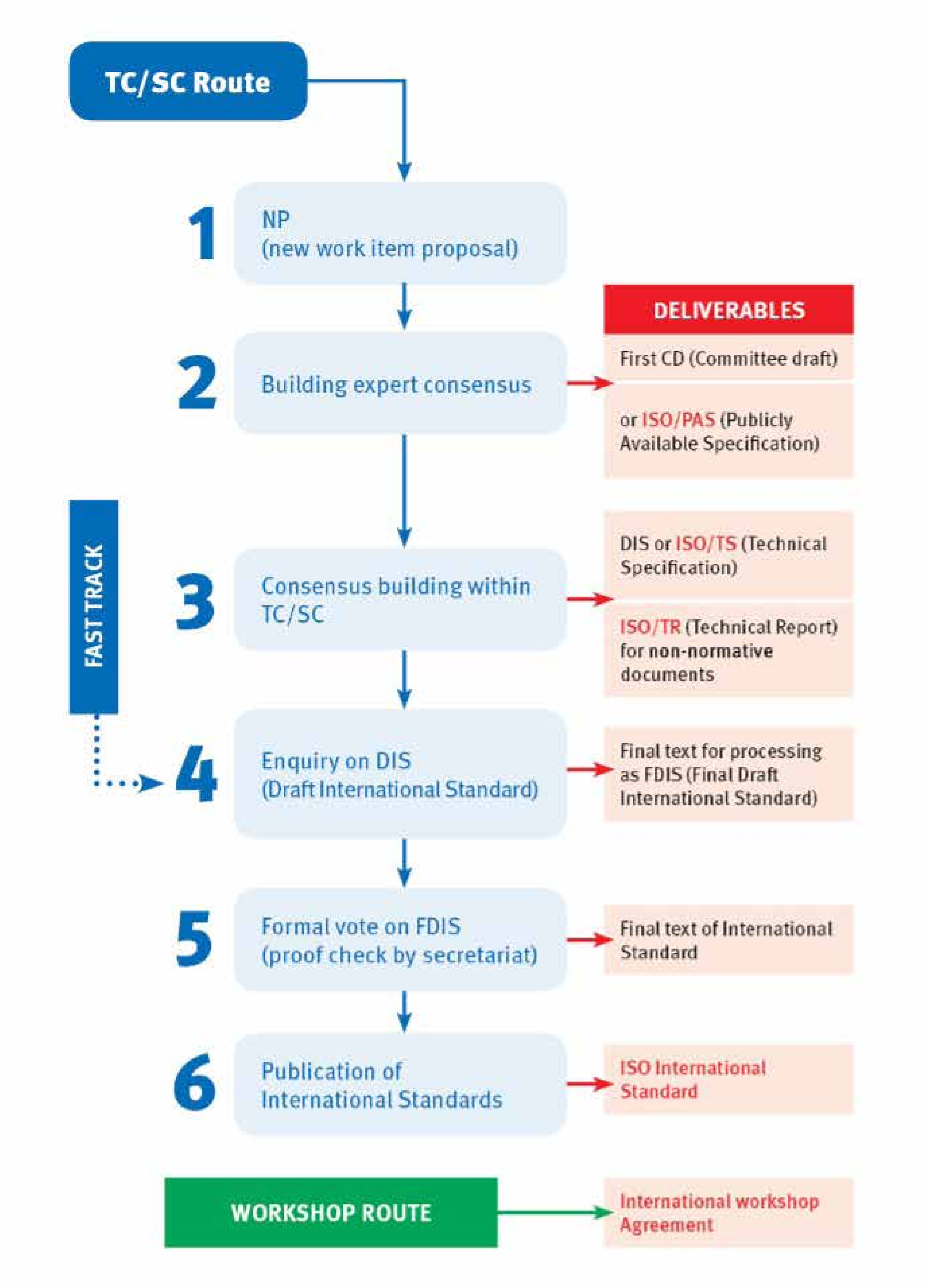
Technology	Sub-area of focus	Process definition statement
Hydrogen	Loading and transport	Hydrogen fuel is loaded at the loading station in bowsers/refueller truck. Fuel is loaded into the truck from the hydrogen storage on site. Quality control is undertaken at the loading station e.g. purity of the fuel, required pressure, temperature and flow control. Fuel is transported to the apron.
Hydrogen	Distribution network	Distribution of hydrogen within the airport environment from storage tank to loading station and to the hydrant pipeline.
Hydrogen	Hydrogen refuelling vehicles	Hydrogen refuelling vehicles - Hydrogen would be transported by the bowsers/refueller truck from fuel loading station to the aircraft. Liquid hydrogen bowsers/refueller truck would have the insulated container. Gaseous hydrogen bowsers/refueller truck would have the high-pressure tank and compressor and cooler.
Hydrogen	Fuel hydrant systems	Fuel is transferred to the apron from the fuel storage (fuel farm) via the underground pipeline network with fuel dispensing hydrants at the apron.
Hydrogen	Fuel cell and tank swapping	Hydrogen tank or fuel cell swapping technology. When airplane lands the empty or low on fuel tank would be swapped with the full tank, using automated operation. Full fuel tank would be delivered from warehouse/storage facility. Empty tank would be moved to warehouse/storage facility for refuel.
Hydrogen	Safety	Oversight for assessing, vetting, mitigating, managing and controlling safety aspect to infrastructure technology, data and systems or components or as part of compliance with airport safety approach.
Hydrogen	Security	Oversight for assessing, vetting, mitigating, managing and controlling threats to infrastructure technology, data and systems or components or as part of compliance with airport security approach.
Hydrogen	Operations	Set of systems and principles to oversee and manage safe, effective and efficient use of systems, resources and deployment in alignment with regulatory requirements and the airport decision making structures.

Technology	Sub-area of focus	Process definition statement
Electric	Energy storage	Energy storage. Due to imbalances in energy production (peaks and lows) energy needs to be stored for the later use. Energy storage is capture of the peak energy that cannot be used at that time and storing it for the later use. Battery storage is the most common use of energy storage currently used. Energy surplus -Sometimes produced energy outstrips the demand. Energy produced that is more than required for the system is surplus energy. Energy storage management - Energy storage facility provides Power supply for fixed wire and mobile charging systems along with other utilities at the airport when required. Energy storage system is optional system to be used to store the energy for the charging infrastructure when power is surplus from the onsite generation, or tariff is low. It can work as buffer for supply and demand changes
Electric	Cable network	Power distribution:- The distribution of power to and from the various sub-systems involves high voltage and low voltage systems and is likely to require significant installation work, particularly where cabling is routed underground. Cable - 'An electrical cable is an assembly of one or more wires running side by side or bundled, which is used to carry electric current. Adaptor - An adapter or adaptor is a device that converts attributes of one electrical device or system to those of an otherwise incompatible device or system
Electric	Battery transport	Battery transport - Movement of batteries within the airport environment from the storage warehouse to the aircraft
Electric	Charging systems	Battery charging facilities can either be one combined facility with energy storage or separate facility for Charging batteries required for battery swapping. Facility is used to store and charge various battery size modules required for battery swapping for all the electric/hybrid aircraft based in the airport.
Electric	Battery swapping	Battery swapping - consists of replacing the discharged battery modules of an aircraft with charged battery modules from the battery charge and storage facility. Due to the expected size and weight of the battery modules a vehicle with loading and unloading capability will be needed. The loading and unloading of battery modules need care to avoid damaging them – automation of some or all of the process may be needed. Automation of the transport vehicle may also aid this process.

Technology	Sub-area of focus	Process definition statement
Electric	Safety	Oversight for assessing, vetting, mitigating, managing and controlling safety aspect to infrastructure technology, data and systems or components or as part of compliance with airport safety approach.
Electric	Security	Oversight for assessing, vetting, mitigating, managing and controlling threats to infrastructure technology, data and systems or components or as part of compliance with airport security approach.
Electric	Operations	Set of systems and principles to oversee and manage safe, effective and efficient use of systems, resources and deployment in alignment with regulatory requirements and the airport decision making structures.

Annex D – ISO Standards development process

The below describes the typical standards development process, where new standards development work item proposals are approved by committees and then follow a process from development of a first committee draft, further consensus building with the technical committee, production of a draft or DIS (Draft International Standard) for public enquiry, formal vote on the final wording through to publication. This process is fairly typical but may vary for different standards development organisations, with a greater onus on developing consensus through more formal standards development processes.



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