WORK HEALTH AND SAFETY RESEARCH HORIZON SCAN, SCOPING REVIEW AND EVIDENCE GAP MAPPING PROJECT

Scoping review and case study findings: Effectiveness of systems and frameworks

A report prepared for Safe Work Australia

ACADEMY OF THE SOCIAL SCIENCES IN AUSTRALIA

ATSE

About this project

This project was commissioned by Safe Work Australia, and it maps the existing landscape of work health and safety and workers' compensation research across the five Safe Work Australia *Research and Evaluation Strategy* initial priority areas to provide a data driven understanding of the current evidence base, gaps, and emerging research areas.

This report was developed with guidance from an Expert Working Group of experts from across work health and safety research and related areas. The Academy of the Social Sciences in Australia and the Australian Academy of Technological Sciences and Engineering gratefully acknowledges the Expert Working Group for their contributions.

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Introduction

This report is part of a series of five reports presenting the consolidated findings from a scoping literature review, horizon scan, and evidence gap mapping undertaken by the Academy of the Social Sciences in Australia for Safe Work Australia (SWA) as part of the 2025 Horizon Scan & Evidence Gap Mapping Project. Each report in the series focuses on one of five research priority areas from SWA's Research and Evaluation Strategy, supported by a case study looking into a known and related driver of change for Work Health and Safety (WHS) in Australia over the coming decade.

The purpose of the project is to ensure future research development, policy and regulatory decisions are evidence informed. To achieve this, each report brings together the results from three integrated research methods. A scoping literature review that maps the depth, breadth and characteristics of Australian WHS and workers' compensation research for a research priority area, a horizon scan which, using a case-study based approach, evaluates research related to a known driver of change to to examine how it is manifesting in relation to WHS research, and an evidence gap mapping that integrates insights from the scoping literature review and the horizon scan to show where the evidence is absent, sparse, or misaligned between the evidence base, priority area and case study.

Together, these methods help us understand what evidence currently exists, how it is distributed across research priority areas and case studies, and how well positioned the Australian research evidence base is to respond to future WHS challenges. The following sections present a summary of key findings that integrates insights from the scoping literature review, horizon scan, and evidence gap mapping. The remainder of the report then unpacks these findings in detail.

Research Priority Area	Case Study	
P1: Psychosocial harm prevention and recovery	C1: Psychological injury and increasing time off work	
P2: Advances in technology	C2: GenAI and work design	
P3: Shifting mindsets around WHS fundamentals	C3: Respect@Work	
P4: Effectiveness of systems and frameworks	C4: Electrification and emerging hazards	✓
P5: Changing nature of work	C5: Algorithmic management in gig platforms	

Effectiveness of systems and frameworks

This report focuses on the research priority area of effectiveness of systems and frameworks identified in SWA's *Research and Evaluation Strategy*.

The effectiveness of systems and frameworks priority area is interested in how Australia's work health and safety, injury management, and workers' compensation systems function in practice, particularly in the context of changing work, emerging risks, and evolving policy settings.

Research in this priority area examines whether legislative frameworks, regulatory arrangements, and supporting systems operate as intended, and where gaps may exist between policy expectations and real-world outcomes. Research seeks to better understand the impacts of changes to WHS and compensation systems, including the degree to which harmonisation is effective, where inconsistencies persist across jurisdictions, and how regulatory and compensation models influence prevention, recovery at work, and long-term worker outcomes. It also considers how systems respond to new forms of work, emerging technologies, and complex risk environments, and whether existing arrangements remain fit-for-purpose under these conditions.

The effectiveness of systems and frameworks represents a defined and focused component of the Australian WHS evidence base. The scoping review identified 398 publications within the 7,027-record dataset as directly relevant to this priority area (collectively referred to as P4). Publication activity has increased steadily over the fifteen-year period examined, indicating sustained research attention to system performance, regulatory arrangements and compensation structures.

Taxonomy-based analysis shows widespread use of system-related language across the broader dataset. High-frequency terms such as monitoring, work design, safety climate and safety management systems appear regularly and are applied to a large number of publications. However, more explicitly evaluative and governance-oriented terms such as harmonisation, regulatory consistency, assurance mechanisms, officer duties, and formal system methodologies appear infrequently or not at all. This pattern suggests that systems are commonly referenced as the context within which hazards and injuries are managed, but less frequently examined as the primary object of evaluation.

System-generated concept clustering reinforces this interpretation. The priority area dataset is organised around health outcomes, compensation pathways, intervention delivery and regulatory responsibility. Workers, return to work and measured outcomes appear as dominant organising topics. Taken together, these findings indicate that the P4 evidence base is oriented toward how systems respond to harm and administer recovery, with less focus on how systems are designed, evaluated or adapted over time.

Electrification and emerging hazards

The case study of electrification and emerging hazards (designated C4) was selected for horizon scanning to highlight Australia's energy transition as a known and emerging driver of change with the potential to impact WHS in Australia over the next decade.

Australia's rapid transition toward electrification, through electric vehicles (EVs), energy storage systems, and advanced manufacturing, presents a new generation of WHS risks and hazards. As lithium-ion battery production, handling, and recycling scale, workers are likely to be increasingly exposed to complex chemical, thermal, electrical and environmental hazards. Alongside these shifts, the broader energy and digital transitions introduce parallel emerging challenges, including new patterns of electromagnetic field (EMF) exposure associated with high-voltage infrastructure, wireless power transfer, and dense industrial digital networks. Together, these trends demand WHS systems that can manage stacked, interacting hazards while supporting safe innovation in the energy transition.

In this context electrification is not a single hazard but a converging one, where energy transition, automated manufacturing, wireless infrastructures and emerging materials interact to create complex WHS challenges and opportunities for proactive, systems-based safety design.

The case study of electrification and emerging hazards provides a forward-looking lens on how existing systems and frameworks may perform under changing technological and industrial conditions. The horizon scan identified 8 publications directly relevant to this case study, all appearing in recent years, reflecting the emerging nature of this driver of change.

Concept analysis of the case study dataset shows a narrow and technically focused evidence base. Publications cluster around lithium-ion battery materials, battery systems, electric vehicles and related safety processes. Only two publications were tagged with any taxonomy term from the full 304-term matrix, and co-occurrence between electrification-related concepts and system-level evaluation terms is minimal.

The horizon scan signals indicate that electrification is not introducing entirely new hazards, but is reconfiguring established electrical risks within new industrial contexts, scales and lifecycle stages. However, these emerging configurations are only weakly reflected within the screened priority area evidence base. Electrification-related research tends to focus on technical hazard characteristics rather than on how regulatory, assurance or compensation systems will operate under conditions of large-scale energy transition.

The case study therefore functions as a stress test for the priority area. It highlights an emerging context in which established knowledge remains relevant, but where the interaction between hazard, system design and regulatory preparedness has not yet been extensively tested.

Evidence gap mapping

Evidence gap mapping integrates the scoping review and horizon scan findings to identify patterns of absence, sparsity and alignment.

At the level of absence, a substantial number of priority area taxonomy terms show no explicit coverage within the dataset. Terms relating to governance, formal system methodologies, assurance mechanisms, evaluation of regulatory effectiveness and system integration are rarely or never applied. This suggests that while systems language is widely used, explicit evaluation of system performance and design remains limited within the screened evidence base.

Sparsity is evident in relation to electrification and emerging hazards. Only eight publications were identified for the case study, and few of these intersect with system-level taxonomy terms. This limits the capacity to draw conclusions about how existing WHS and compensation frameworks are being examined in relation to the energy transition.

The primary alignment gap concerns the relationship between established system research and emerging hazard contexts. The scoping literature review demonstrates a mature body of research examining compensation pathways, return to work and regulatory compliance under relatively stable hazard conditions. The horizon scan, by contrast, highlights changing configurations of risk associated with electrification, automation and lifecycle complexity. The limited co-occurrence between these domains indicates that system-level concepts are not yet being tested against newly electrified work environments or changes driven by the energy transition.

Taken together, the findings suggest that the evidence base contains substantial knowledge about system operation under established conditions, but provides more limited insight into how systems and frameworks will perform as hazard environments evolve. Electrification serves as a revealing case study in this respect, indicating that the central evidence gap lies not in foundational understanding of systems or electrical hazards, but in the integration of these domains.

Key findings

The Australian WHS evidence base for the effectiveness of systems and frameworks is established and growing. The scoping review identified 398 publications within the 7,027-record dataset as directly relevant to this priority area, with consistent increases in publication volume over the past fifteen years. System-related language is widely used across the broader dataset, and high-frequency taxonomy terms such as monitoring, work design, safety climate and safety management systems appear regularly. This indicates that systems and frameworks are well embedded within the WHS research landscape.

However, taxonomy-based analysis shows that explicit evaluation and governance concepts are comparatively underrepresented. Terms relating to harmonisation, regulatory consistency, assurance mechanisms, officer duties, formal system methodologies and evaluation of regulatory effectiveness appear infrequently or not at all. While systems are commonly

referenced as the context within which hazards are managed and injuries are processed, they are less often examined as dynamic objects of study in their own right. Topic clustering reinforces this pattern, with the literature organised primarily around health outcomes, compensation pathways, return to work, and intervention delivery rather than around system design, performance or adaptation.

The electrification case study provides a forward-looking test of system readiness. The horizon scan identified only eight publications directly addressing electrification-related hazards within work contexts, all appearing in recent years. These publications are narrowly focused on lithium-ion batteries and related technical safety processes, and show minimal co-occurrence with system-level taxonomy terms. Emerging signals suggest that established electrical hazards are being recombined within new industrial contexts, lifecycle stages and scales of operation associated with the energy transition. However, this reconfiguration is only weakly reflected in the screened priority area evidence base.

Taken together, the findings indicate that the Australian WHS evidence base contains substantial knowledge about how systems respond to injury and manage established risks. The primary evidence gap lies not in foundational understanding of systems or hazards, but in the limited extent to which existing system concepts are explicitly evaluated or tested under evolving hazard conditions. Electrification illustrates this integration challenge, highlighting a gap between established system research and the changing configurations of risk associated with the large-scale energy transition. This pattern suggests an evaluation gap: systems are widely referenced and operationalised, but comparatively less attention is directed toward assessing how they perform or adapt as work environments change.

Scoping literature review

This scoping review draws on the full dataset of 7,027 records (see Appendix 1) to provide an overview and synthesis of the WHS research landscape for the research priority area of effectiveness of systems and frameworks (P4). The 398 records screened by the AI panel form a focused subset of this dataset, here they are compared and contrasted with the full dataset to understand priority area research and taxonomy coverage.

Tagging results

Across the taxonomy, 62 P4 taxonomy terms were operationalised to tag the 7,027 records in the full dataset (a record may have multiple tags). Of those terms, 27 appeared in the title or abstract of at least one publication, while 35 terms did not appear on any publications (see Appendix 3 for a list of terms and their frequency).

Table 1 shows that a total of 371 tags were applied to records in the P4 priority area, 97 of those tags were from the P4 taxonomy. The total number of P4 tags applied (1,103) was significantly greater than the number of tags applied to P4 records (97), indicating that many publications reference P4-related concepts without being screened as primary sources for this priority area.

Appendix 3 presents the distribution of P4 taxonomy terms assigned to records in the datasets ordered by total publication count. It shows that coverage is uneven, with a small number of taxonomy terms accounting for a large proportion of publications and a long tail of terms with relatively low counts.

The most frequently observed P4 taxonomy terms were *monitoring* (245), *work design* (219), *safety climate* (132), *safety management system* (65), *incident analysis* (52), *and cost of injury* (49). Together, these relatively highest-frequency terms account for the majority of P4 taxonomy-tagged publications, particularly the top three terms of *monitoring, work design* and *safety climate*.

In contrast, many taxonomy terms were associated with relatively small numbers of publications. Thirteen taxonomy terms appeared on fewer than 10 publications, and many appeared only once or twice. This comprised a diverse set of terms, such as *risk tolerance, uncertainty management, exposure standards,* and *participatory evaluation*.

Thirty-five taxonomy terms were not associated with any publications, indicating an absence of explicit coverage for these concepts within the dataset. Absence in this context refers to a lack of explicit taxonomy tagging in the dataset and does not imply the absence of research on these subjects more broadly. Examples include terms such as *Occupational Health and Safety Management Systems* (*OHSMS), Incident Cause Analysis Method (ICAM), Human Factors Analysis and Classification System (HFACS), responsive regulation,* and *worker centred evaluation*.

Tags applied	Screened record categories							
	P1	P2	P3	P4	P5	Unscreened	Multi***	Total**
P1	2079	140	625	183	138	1843	678	4330
P2	63	232	49	24	28	388	66	718
P3	68	40	77	41	19	183	58	370
P4	130	144	226	97	29	477	126	977
P5	150	37	55	26	45	406	71	648
Total*	2490	593	1032	371	259	3297	999	7043

Table 1: A matrix showing the number of tags applied to screened records across the 7,027-record dataset. P4 tags are highlighted. The Y-axis is priority area tags and X-axis is the screened record categories, e.g. cell P4/P4 shows the number of P4 tags applied to P4 screened records. The table also includes columns with the number of unscreened records that were tagged, the number of tags that were counted multiple times (Multi) and the total tags applied. Figures reflect total tag counts, tagging is not exclusive and a term might appear on records in each priority area, records can also be screened into more than one priority area – hence tag counts are higher than the number of records in the dataset.
** Total tags on P1, P2, P3 etc. records, **Total P1, P2, P3 tags on all records. ***The number of terms that are counted more than once.*

Patterns over time

Time-based analyses of the 398 screened records show consistent growth in output across the period covered by the dataset (Table 2), with higher volumes observed in more recent years and consistent year-on-year growth over the fifteen-year period. Figure 1 shows the top ten terms over the period, and the number of publications tagged in the full dataset. This highlights the consistent and stable growth of research on key P4 topics within the dataset. When it comes to P4 terms, coverage grows over time but is significantly greater than the number of screened P4 publications, suggesting the taxonomy has a much broader scope than the priority area.

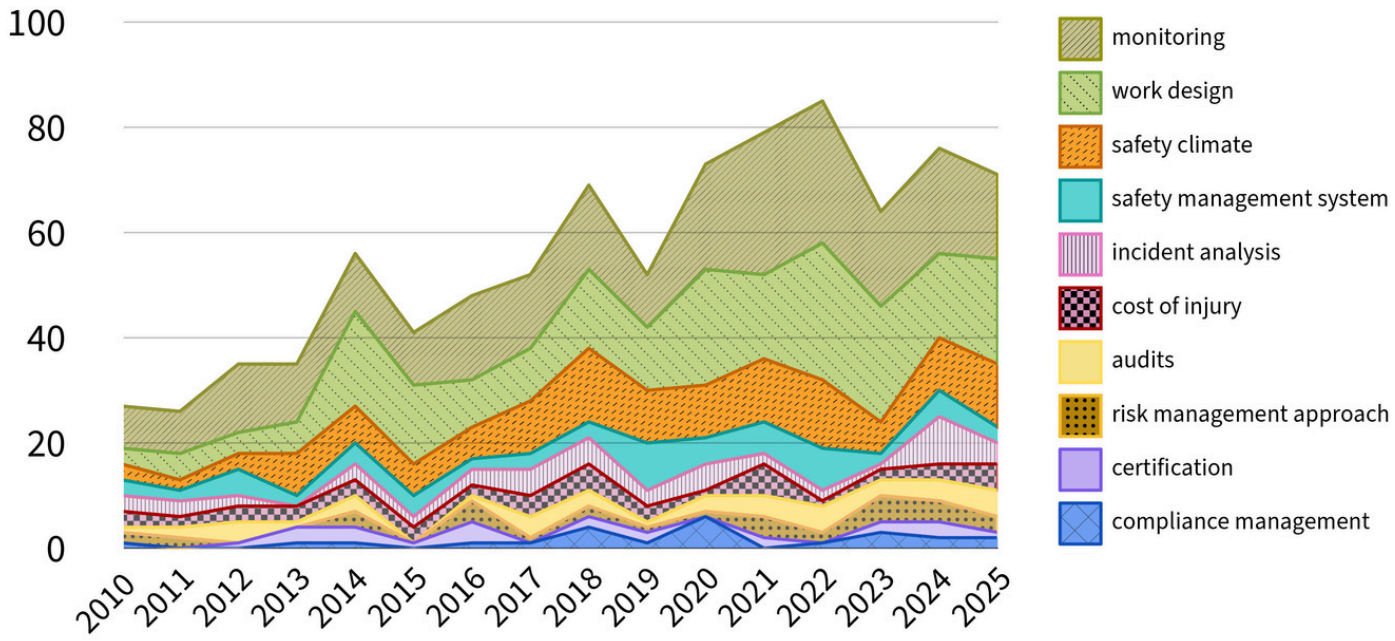

Figure 1: Stacked area chart of the top ten terms by year and number of publications tagged in the full dataset.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Pubs	11	9	16	15	21	18	25	23	31	31	33	28	38	26	39	34
Tags	27	26	35	35	56	41	48	52	69	52	73	78	85	64	76	71

Table 2: Table showing the number of P4 publications, and records with P4 tags by year of publication.

High-level concept clusters derived from VOSviewer

To complement taxonomy-based tagging, high-level concept clusters were generated using VOSviewer[1] based on co-occurrence of key terms in titles and abstracts within the P5 screened dataset. This approach provides an inductive, data-driven view of how concepts are organised in the dataset, enabling comparison between emergent research themes and the deductively defined P4 taxonomy.

The P4 concept network is dominated by health effects, recovery processes, and formal programs of intervention, with workers and return to work appearing as the most frequent concepts. These terms co-occur most strongly with health, outcomes, intervention, and compensation-related concepts, indicating that the evidence base is organised around measured effects and managed responses to harm. Governance and regulatory concepts sit centrally in the network and appear alongside intervention and outcome terms, linking safety research to policy, compliance, and organisational responsibility. In contrast, specific hazards, tasks, or exposure mechanisms are weakly represented, suggesting they are not primary organising concepts in this priority area. Overall, the network shows P4 as a body of research focused on what happens after harm occurs, how it is measured, managed, and responded to.

The clusters are presented in Table 3, and Table 4 lists the top 5 concepts. The cluster/concept network is visualised in Appendix 4 Figure 2.

#	Cluster	Concepts	Description
1	Regulation, governance, and organisational responsibility	45	This cluster focuses on the institutional and governance context of WHS, including law, regulation, policy, organisational responsibility, management systems, and employer obligations.
2	Health service settings, prevention, and intervention delivery	35	This cluster centres on intervention activity within health and care settings.
3	Compensation systems and injured worker pathways	30	This cluster captures how work-related injury is processed through compensation schemes.

[1] *Nees Jan van Eck and Ludo Waltman, "Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping," Scientometrics 84, no. 2 (2010): 523–538, https://doi.org/10.1007/s11192-009-0146-3.*

#	Cluster	Concepts	Description
4	Health outcomes, mental health, and injury effects	25	This cluster is organised around measured outcomes, including injury, mental health, health status, and secondary outcomes.
5	Evaluation methods and outcome measurement	20	This cluster brings together methodological concepts used to evaluate WHS interventions, including trials, control groups, outcome measures, and study design.
6	Worker capacity, disability, and functional impact	20	This cluster centres on workers' functional capacity and longer-term consequences of injury, including disability, pain, income support, healthcare use, and functional outcomes.

Table 3: The clusters resulting from VOSviewer analysis, number of concepts included, and summary descriptions.

Concept	Occurrences	Cluster
Workers	68	3
Return to work	48	3
Health	40	4
Outcomes	33	4
Intervention	28	2

Table 4: The top five concepts by the number of occurrences, and their associated cluster.

Publication profile

The P4 publication profile shows a high degree of concentration around occupational health, rehabilitation, and injury-focused journals, with Occupational and Environmental Medicine and the Journal of Occupational Rehabilitation clearly dominant (Table 5). This indicates that P4 research is most often published in outlets concerned with health outcomes, injury prevention, and recovery processes. Organisationally, output is strongly concentrated in a small number of Australian universities, with Monash University standing out as a major hub, contributing far more publications than any other institution (Table 6). The presence of several other large research-intensive universities suggests a clustered but not widely dispersed institutional base
.

The author profile reinforces this pattern of concentration. A small group of authors appears repeatedly across the dataset, with Alex Collie and Tyler Jeremiah Lane accounting for a substantial share of publications, alongside a handful of frequent collaborators (Table 7). This

points to stable, programmatic research activity, rather than a fragmented or highly distributed authorship landscape. Taken together, the source, organisation, and author patterns suggest that P4 is driven by established research groups publishing repeatedly in a narrow set of specialised journals, shaping the evidence base around health outcomes, injury, and rehabilitation themes.

Source Title	Publications
Occupational and Environmental Medicine	19
Journal of Occupational Rehabilitation	15
International Journal of Environmental Research and Public Health	10
Injury Prevention	10
The APPEA Journal	10

Table 5: The top five publication sources by the number of associated publications.

Organisation	Publications
Monash University	68
The University of Sydney (USYD)	25
University of Melbourne	22
UNSW Sydney (UNSW)	20
Griffith University	18

Table 6: Top five affiliated organisations noted on publications, by number of publications they are listed on.

Author	Publications
Alex Collie	29
Tyler Jeremiah Lane	18
Shannon Elise Gray	12
Ross Anthony Iles	11
Michael F Di Donato	10

Table 7: Top five authors, by the number of publications they are listed on.

Summary of taxonomy-based evidence coverage

The taxonomy-based analysis provides a structured overview of how research is distributed across the Australian WHS evidence base for the effectiveness of changed systems, legislative frameworks and other policy settings priority area. Overall, the tagging results indicate broad and consistent use of system-related language across the literature, with most publications associated with multiple system and framework concepts. High-frequency taxonomy terms include *safety management systems, continuous improvement, digital WHS systems,* and *intervention-related concepts,* reflecting the extent to which WHS research is commonly situated within formal organisational and regulatory contexts.

At the same time, the taxonomy reveals a more uneven pattern beneath this surface coverage. Concepts that more directly capture the evaluation, governance, or comparative performance of systems and frameworks appear infrequently. Tags relating to governance, audits, harmonisation, accreditation, assurance mechanisms, and formal system methodologies are applied to only a small proportion of publications. This indicates that while systems and frameworks are widely referenced, they are less often examined as the primary object of analysis. In many cases, system-related terms appear as contextual framing for studies focused on specific hazards, exposures, or workplace interventions, rather than as focal points for empirical evaluation.

The taxonomy also highlights strong coverage of worker groups and work contexts that are commonly associated with elevated WHS risk, including high-risk industries, non-standard work arrangements, multi-party worksites, and small business settings. These contextual tags appear frequently across the dataset, suggesting that the literature recognises environments where system complexity and coordination challenges are likely to arise. However, the co-occurrence patterns indicate that research in these contexts is typically oriented toward hazard-level or organisational issues, with comparatively limited attention to how systems and frameworks themselves function or adapt within these settings.

Taken together, the taxonomy-based evidence coverage suggests that the Australian WHS research contains a substantial foundation of system-adjacent research, but a more limited body of work that explicitly interrogates the effectiveness, design, or evolution of systems and frameworks.

Horizon scan

The horizon scan was conducted following a case-study based deductive approach that recognises existing research on the future of work health and safety and known drivers of change. Drivers of change identified by leading international institutions and global WHS research programs were used as an organising frame for the horizon scan and to help manage its scope. These drivers represent well-established and emerging trends on the global WHS horizon. A case study approach was then used to examine how these identified drivers are manifesting within the Australian WHS research evidence base. Case studies were selected through literature review and in consultation with SWA and the project's Expert Working Group (EWG).

Case study	Drivers of change	Rationale	Time frame	Publications	Publishing	Status
Electrification & Emerging Hazards	Green energy transition; technology scale-up (EVs, storage); new materials and chemistries, energy carriers and storage	The case study captures the topics of governance, risk control, and system readiness for green-transition hazards (lithium, hydrogen, and energy storage)	Relevant on the 6-to-10-year horizon	8	Since 2011, increasing since 2020	Emerging

This section presents the results of analysis for the case study of electrification and emerging hazards which reflects the importance of Australia's clean energy transition as a driver of change for WHS. The case study topic was selected for this priority area to provide a specific focus on research relevant to the effectiveness of systems and frameworks, and topics such as governance, risk control, and system readiness for energy transition hazards (lithium, hydrogen, and energy storage). Australia's energy transition and related changes in areas such as electrification are seen as driving significant change over the next six to ten years.

Overview of results

The case study dataset comprises 8 publications identified through the AI screening method (See Appendix 1). Records were tagged with terms from the full taxonomy of 304 terms across the five priority areas. The purpose was to examine the cross-cutting nature of the research and related concepts across the priority areas.

Across these 8 records, only 2 were tagged with at least one taxonomy term from the full taxonomy of 304 terms. The two terms were *incident analysis* and *end user (see the summary in Tables 8 and 9).*

Measure	Number of publications
Publications in the case study	8
Publications with ≥1 taxonomy tag in the matrix	2
Publications with no taxonomy tags in the matrix	6

Table 8: Summary of the publications included in the case study and taxonomy tagging results.

Taxonomy term	Priority Area	Publications
Incident analysis	P4	1
End user	P5	1

Table 9: Top five taxonomy terms by the number of publications tagged, using the full taxonomy of 304 terms.

Patterns over time

Time-based analyses show that publications appear in more recent years (Table 10). This pattern is consistent with results seen in the scoping review and that makes sense given the emerging status of electrification.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Freq	0	1	0	0	1	0	1	0	0	0	1	2	0	0	2	0

Table 10: The number of publications per year in the case study dataset.

High-level concept clusters from VOSviewer

System-generated concept clusters derived from VOSviewer provide a complementary, high-level overview of concept co-occurrence.

The C4 concept network shows a highly concentrated and narrow evidence base focused on lithium-ion batteries and related concepts, as well as batteries, vehicles and safety concepts. Concepts cluster around lithium-ion batteries and related applications, such as their use in vehicles. These results are presented in Tables 11 and 12, and visualised in Appendix 4 Figure 3.

#	Cluster	Concepts	Description
1	Lithium-ion battery materials, performance, and degradation	65	This cluster is dominated by highly technical concepts relating to lithium-ion battery chemistry and material science.
2	Battery packs, electric vehicles, and safety-related system processes	10	This cluster brings together applied concepts relating to battery packs, electric vehicles, recycling, disassembly, and occupational safety.

Table 11: The clusters resulting from VOSviewer analysis, number of concepts included, and summary descriptions.

Concept	Cluster	Occurrences
Battery	2	2
Battery pack	2	2
Electric vehicles	2	2
Li-ion batteries	1	1
Occupational safety	2	1

Table 12: Table showing top 5 concepts and the associated cluster.

Comparison of scoping literature review and horizon scan results

The comparison between the scoping literature review and the horizon scan highlights a clear divergence between the evidence base informing P4 and the forward-looking pressures identified through the electrification case study.

The scoping literature review is dominated by established system concerns, including regulatory compliance, compensation scheme design, claims processes, and safety management systems. This body of evidence reflects a mature and well-developed evidence base addressing how WHS and workers' compensation systems have historically operated and responded to known risks. Concept clusters derived from the scoping review reinforce this focus, with strong representation of regulatory jurisdictions, administrative processes, and injury and claims outcomes. Collectively, this suggests that the P4 evidence base is oriented toward system performance under relatively stable hazard conditions.

By contrast, the horizon scan surfaces a set of future-oriented concepts that sit only partially within the conceptual boundaries of the existing evidence base. While electrification-related terms do appear within the literature, they often appear together with adjacent terms such as general electrical safety, electromagnetic fields, or industrial technology; this suggests that electrification is being framed in a historic context, rather than being re-examined through system design, regulatory capability, or compensation preparedness in the wake of Australia's energy transition.

The horizon scan therefore reveals that while research may be lagging, the energy transition is advancing rapidly as a national policy and industry priority, the WHS and workers' compensation literature does not appear to reflect this significance. Emerging issues such as high-energy battery systems, thermal runaway, toxic by-products, emergency response complexity, and cross-jurisdictional consistency show limited representation. These issues are visible as weak signals picked up in the horizon scan across the full dataset and were not present in the screened P4 evidence base.

Taken together, this comparison suggests that the existing evidence base can provide only limited insight into how current WHS regulatory and compensation frameworks will perform under the conditions created by large-scale electrification driven by Australia's energy transformation.

Signal scanning

Signals represent observable directional patterns and configurations within the existing evidence base that may warrant monitoring or further investigation. Signals were identified using the horizon scanning questions and criteria specified in the horizon scanning methodology, focusing on: changes in volume or concentration of research activity; shifts in conceptual emphasis; recombination or co-occurrence of concepts; boundary-crossing across domains or priority areas; and consolidation or dispersion of the evidence base. The signals identified in Table 15 do not, in themselves, constitute evidence gaps. Rather, they provide structured inputs for evidence gap mapping.

In the context of the clean energy transition, several signals reflect situations where hazards that are often treated as established or well understood are now appearing in new settings, interacting with other risks, or affecting different groups of workers, raising questions about whether existing evidence remains sufficient or appropriately framed.

For example, recent work on underground mobile fleet electrification in mining explicitly examines battery-electric vehicle risks in confined underground environments, reframing electrical hazards in relation to ventilation, thermal load, and emergency response conditions.[2] Similarly, research on automated disassembly of electric vehicle battery systems illustrates how electrical hazards re-emerge at different stages of the battery lifecycle, particularly where residual charge and automation intersect.[3]

Signal	Measure	Insight
Electrification still framed as a legacy hazard	Electrification-related terms appear primarily within traditional electrical safety concepts. Limited differentiation by industry, task, or work setting. Modest but recent publication activity in horizon scan data.	Electrical hazards are generally treated in the literature as well understood and well managed. However, within the clean energy transition, electrification is increasingly occurring in new contexts, including different industries, work arrangements, and physical environments. This signal suggests that while the hazard itself is not new, the contexts in which it is encountered may warrant renewed examination of existing assumptions about exposure, control measures, and risk profiles.
Recombination of electrical hazards with new technologies and work contexts	Co-occurrence of electrification concepts with emerging technologies in horizon scan data.	Rather than introducing new hazards, electrification is recombining with different sources of risk, including automation, advanced manufacturing, transport electrification, and climate-related adaptation. The evidence base doesn't examine how these hazards compound or interact, signalling a gap in understanding how risk profiles change when electrification is embedded within complex socio-technical systems rather than isolated tasks or equipment.
High-energy battery systems challenging traditional hazard assumptions	Very low occurrence counts for battery-specific terms. Technical battery research present but weakly connected to WHS.	High-energy battery systems, central to the clean energy transition, pose challenges for traditional electrical safety assumptions due to their failure modes, delayed ignition risks, and toxic by-products. There is an absence of research in these datasets on these more specific issues.

[2] *Assimi, Hirad, Sayed Nasrollah Hashemian Ataabadi, Shah Mohammad Mominul Islam, Wen Liang Soong, and S. Ali Pourmousavi. "Toward Underground Mobile Fleet Electrification: Three essential steps to make a real change." IEEE Electrification Magazine 12, no. 1 (2024): 16-26.*

[3] *Blankemeyer, Sebastian, Denise Wiens, Tobias Wiese, Annika Raatz, and Sami Kara. "Investigation of the potential for an automated disassembly process of BEV batteries." Procedia CIRP 98 (2021): 559-564.*

Signal	Measure	Insight
Shifts in who is exposed to electrical risks and where exposure occurs	Limited attention to worker characteristics, employment arrangements, or non-traditional worksites in electrification-related research.	As electrification expands, electrical risks are increasingly encountered by workers outside traditionally electrical trades and in less controlled environments. The horizon scan suggests an emerging signal that the distribution of exposure is changing, raising questions about whether existing evidence adequately reflects who is now encountering these risks and under what conditions.

Table 13: Table of horizon scanning signals.

Evidence gap mapping

This evidence gap mapping brings together results from the scoping review and the horizon scan case study to systematically document gaps in the evidence base, drawing on patterns in taxonomy tagging, temporal patterns of publication, and concepts and clusters emerging from VOSviewer.

Three kinds of evidence gaps were observed in results from the scoping literature review and horizon scan case study:

- **Absence:** taxonomy terms or concept areas with no explicit coverage;
- **Sparsity:** concepts represented by very small numbers of publications relative to the size of the evidence base; and
- **Alignment:** mismatches between conceptual centrality (as indicated by system-generated concept clusters) and explicit taxonomy coverage.

Absence

Analysis of taxonomy term coverage indicates that there is an absence of specific system-level concepts and emerging hazard framings. Across priority area P4, high-level system descriptors such as *systematic WHS management, continuous improvement*, and *digital WHS systems* are associated with a large proportion of publications. However, terms that more directly capture the evaluation, governance, or comparative performance of systems such as WHS governance, audits, harmonisation, accreditation, ESG alignment, or formal system methodologies are rarely identified. The absence of these terms indicates that, while systems are frequently referenced, they are seldom the object of research.

When examined through the electrification case study, this absence becomes more pronounced. Taxonomy terms specific to electrification, battery systems, and energy transition hazards appear infrequently and are rarely co-tagged with system or framework terms. This suggests that electrification-related risks are not being examined in conjunction with system effectiveness concepts, but instead appear within adjacent technical or hazard-focused framings. As a result, the evidence base lacks studies that explicitly connect emerging electrification contexts with evaluative questions about how existing systems and frameworks operate under these conditions.

Sparsity

Patterns of taxonomy coverage also reveal sparsity in areas where research attention has begun to emerge but remains thin and uneven. Within the priority area P4, contextual tags such as high-risk industries, non-standard work, multi-party worksites, and small business appear frequently, indicating that the literature recognises environments where system complexity is elevated. However, these contextual tags are rarely accompanied by tags relating to system evaluation or governance, suggesting that research in these areas continues to focus on hazards, exposures, or local interventions rather than on system evaluation.

For the case study, sparsity is evident in the limited number of publications tagged with electrification-related terms and the narrow range of accompanying concepts. Where such terms appear, they are typically associated with a small number of technical or engineering-focused tags and are seldom linked to worker characteristics, lifecycle stages, or policy and framework concepts. This sparse tagging pattern constrains the ability to identify consistent themes or trajectories within the evidence base and limits the extent to which emerging insights can be synthesised across sectors or contexts.

Alignment

The taxonomy also highlights a misalignment between the conceptual structure of the existing evidence base, and the changing configurations of risk associated with electrification. Across Priority Area P4, the prevalence of generic systems terminology alongside the absence of evaluative and governance-focused tags suggests that systems are treated primarily as background conditions rather than as dynamic objects of study. This framing aligns with research conducted in relatively stable hazard environments, where established assumptions about exposure and control remain valid.

In contrast, the electrification case study reveals that established electrical hazards are intersecting with new technologies, work processes, and stages of production and disposal. However, the taxonomy shows limited co-occurrence between electrification-related terms and tags associated with system effectiveness, regulatory interpretation, or compensation frameworks. This represents the core challenge for the priority area: while systems and frameworks are central to managing complex risk environments, the evidence base does not appear to examine how existing arrangements perform or adapt as hazards are reconfigured through technological and climate-driven change.

Appendix 1: Data and screening

This section reports on the method and approach followed to conduct the horizon scan, scoping literature review and evidence gap mapping.

The dataset of 7,028 WHS research publications (see Note below) was screened for records relevant to the research priority area of effectiveness of systems and frameworks and the case study of electrification and emerging hazards. Screening was conducted by a panel of four large language models (LLMs) which included ChatGPT 4.1 Mini, Claude 3 Haiku, Gemini 2.5 Flash and Grok 4.1 Fast Reasoning.[4]

The LLMs were asked to classify records into three categories using a schema, primary research, secondary research or irrelevant, and to provide confidence scores along with their decision (see Appendix 2 for instructions given). This information was used to calculate inter-panel agreement following an established method which led to records being labelled as green (high confidence and agreement), amber (intermediate) or red (low confidence and agreement). Only records categorised as primary where the panel showed a high level of confidence and agreement (green records) were selected.

The panel identified 398 records (Table 14) potentially relevant to the effectiveness of systems and frameworks priority area and 8 records (Table 15) relevant to electrification and emerging hazards. These records were then checked by human reviewers for relevance. These records were not excluded but identified for the purpose of comparison and audit. It is the case that there can be a high level of ambiguity and interpretation when deciding if a record, based on its title and abstract, is a primary, secondary or irrelevant source of evidence for a priority focus area or case study.

Results were then tagged with taxonomy terms and described using bibliometrics. The results of this analysis are presented and discussed in the scoping literature review, horizon scan and evidence gap mapping.

[4] *Zhilong Zhao and Yindi Liu, A Confidence–Diversity Framework for Calibrating AI Judgement in Accessible Qualitative Coding Tasks (Guangzhou: School of Journalism and Communication, South China University of Technology, 2025). https://doi.org/10.48550/arXiv.2508.02029.*

	Green	Amber	Red
Primary	398	679	323
Secondary	22	356	223
Irrelevant	2573	2025	429

Table 14: Model ratings and risk matrix for the priority area in the set of 7,028 records (Green – low risk, Amber – medium risk, Red – high risk).

	Green	Amber	Red
Primary	8	23	2
Secondary	0	4	2
Irrelevant	5827	1158	4

Table 15: Model ratings and risk matrix for the case study in the set of 7,028 records (Green – low risk, Amber – medium risk, Red – high risk).

Note: Tables 14 and 15 contain an extra record, which was removed after screening was completed, making the total 7,027.

Appendix 2: Schema and instructions

This appendix presents the instructions provided to large language model (LLM) panel members when reviewing records, and the specific categorisation schemes that were used.

Scheme P	Effectiveness of systems and frameworks
Instruction	This priority area covers the effectiveness of changed systems, legislative frameworks and other policy settings. The research priority area focuses on better understanding the effects and impacts of changes to the legislative frameworks (e.g. where harmonisation could be strengthened, gaps between expectations and reality, determining optimal models for injury management, bridging gaps in compensation policy evidence).
Primary category	The research being reviewed has a clear focus on the effectiveness of changed systems, legislative frameworks and other policy settings for work health and safety
Secondary category	Systems, legislative frameworks and other policy settings are discussed but are not the primary focus for work health and safety.
Irrelevant category	No substantive focus on systems, legislative frameworks and other policy settings for work health and safety.

Scheme C	Electrification and emerging hazards (e.g. from lithium batteries)
Instruction	This case study focuses on electrification of systems, energy transition or storage technologies such as lithium-ion batteries in manufacturing, storage, transport, recycling or maintenance. It includes related emerging work health and safety hazards: fire, explosion, thermal runaway, and new hazard or exposure profiles. As well as systems, standards or regulatory responses to these hazards and the emerging technology in work/workplace contexts, industries and professions such as mining.
Primary category	The main focus is on work health and safety related to electrification, battery and storage technologies, and closely linked hazards, vulnerable contexts and workers' compensation issues.
Secondary category	Electrification, batteries or related hazards are mentioned but are not the main focus OR appear as one example among many.
Irrelevant category	No substantive focus on electrification-related hazards or battery/storage technologies in work health and safety.

Appendix 3: Tagging results

This appendix lists taxonomy terms for the research priority area, ranking them by the total number of records tagged in the full dataset of 7,027 records and providing a breakdown of tagged records in the priority area and case study datasets.

Rank	Normalised term	P4 records tagged	C4 records tagged	Total tagged
1	monitoring	14	0	245
2	work design	19	0	219
3	safety climate	4	0	132
4	safety management system	14	0	65
5	incident analysis	5	1	52
6	cost of injury	6	0	49
7	audits	6	0	44
8	risk management approach	3	0	34
9	certification	3	0	24
10	compliance management	4	0	24
11	regulatory review	5	0	15
12	accreditation	3	0	14
13	business case	1	0	13
14	harmonisation	4	0	10
15	risk tolerance	1	0	8
16	uncertainty management	0	0	6
17	exposure standards	3	0	6

Rank	Normalised term	P4 records tagged	C4 records tagged	Total tagged
18	uncertainty communication	0	0	4
19	participatory evaluation	0	0	3
20	economic dimension of WHS	0	0	3
21	chain of responsibility	1	0	1
22	regulatory consistency	0	0	1
23	WHS software	0	0	1
24	safety apps	0	0	1
25	digital reporting	0	0	1
26	risk perception communication	0	0	1
27	precautionary principle	1	0	1
28	systematic WHS management	0	0	0
29	OHSMS	0	0	0
30	due diligence and governance	0	0	0
31	WHS governance	0	0	0
32	officer duties	0	0	0
33	hierarchy of controls	0	0	0
34	continuous improvement in WHS	0	0	0
35	plan do check act	0	0	0
36	WHS audits	0	0	0

Rank	Normalised term	P4 records tagged	C4 records tagged	Total tagged
37	performance measurement and indicators	0	0	0
38	lagging indicators	0	0	0
39	leading indicators	0	0	0
40	integration with business systems	0	0	0
41	integrated management systems	0	0	0
42	ESG alignment	0	0	0
43	third party certification and assurance	0	0	0
44	Regulatory compliance systems	0	0	0
45	legal registers	0	0	0
46	supply chain WHS assurance	0	0	0
47	procurement standards	0	0	0
48	cross jurisdictional coordination	0	0	0
49	evaluation of regulatory effectiveness	0	0	0
50	effectiveness indicators	0	0	0
51	digital WHS systems	0	0	0
52	worker centred evaluation	0	0	0
53	lived experience metrics	0	0	0
54	responsive regulation	0	0	0
55	flexible regulation	0	0	0

Rank	Normalised term	P4 records tagged	C4 records tagged	Total tagged
56	agile regulation	0	0	0
57	learning from incidents	0	0	0
58	ICAM	0	0	0
59	HFACS	0	0	0
60	conservative controls	0	0	0
61	occupational hygiene exposure science	0	0	0
62	Intervention	0	0	0
	Total	**97**	**1**	**977**

Appendix 4: Network visualisations

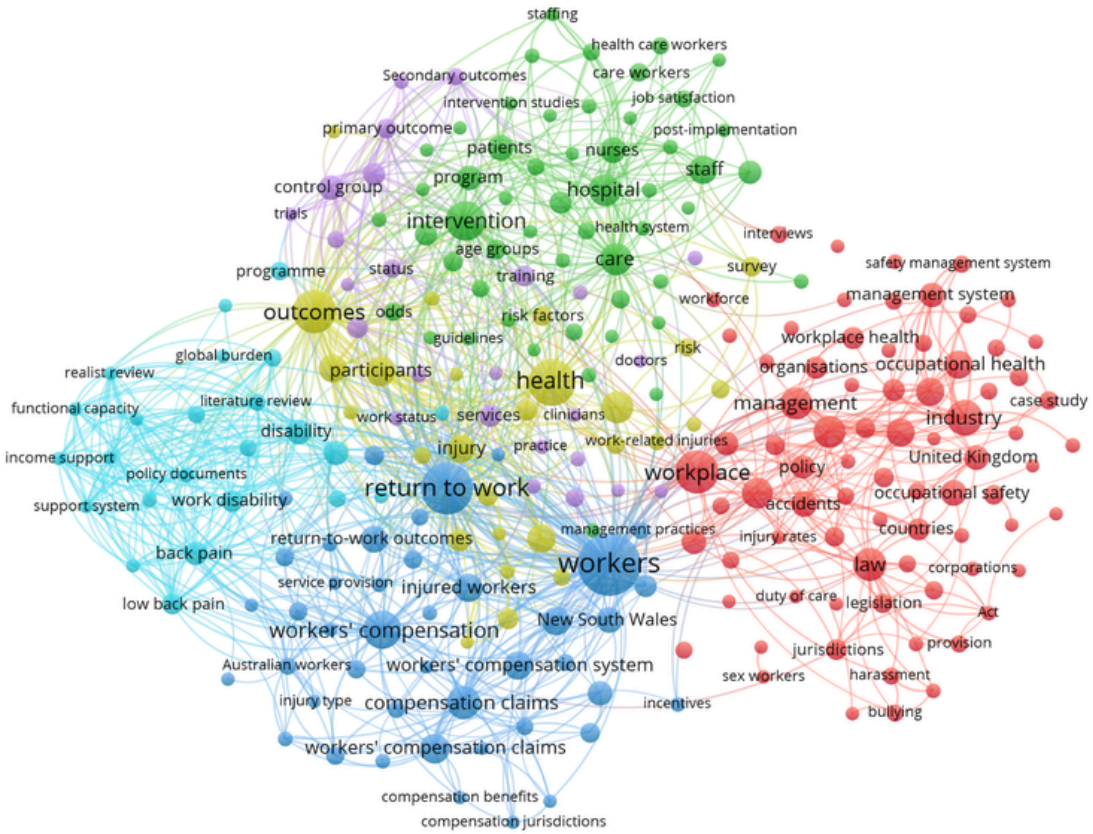

Figure 2: Co-occurrence network map for 250 concepts derived from titles and abstracts in the priority area dataset using VOSviewer. Cluster 1:red, Cluster 2: green, Cluster 3: blue, Cluster 4: yellow, Cluster 5: purple, Cluster 6: teal/light blue.

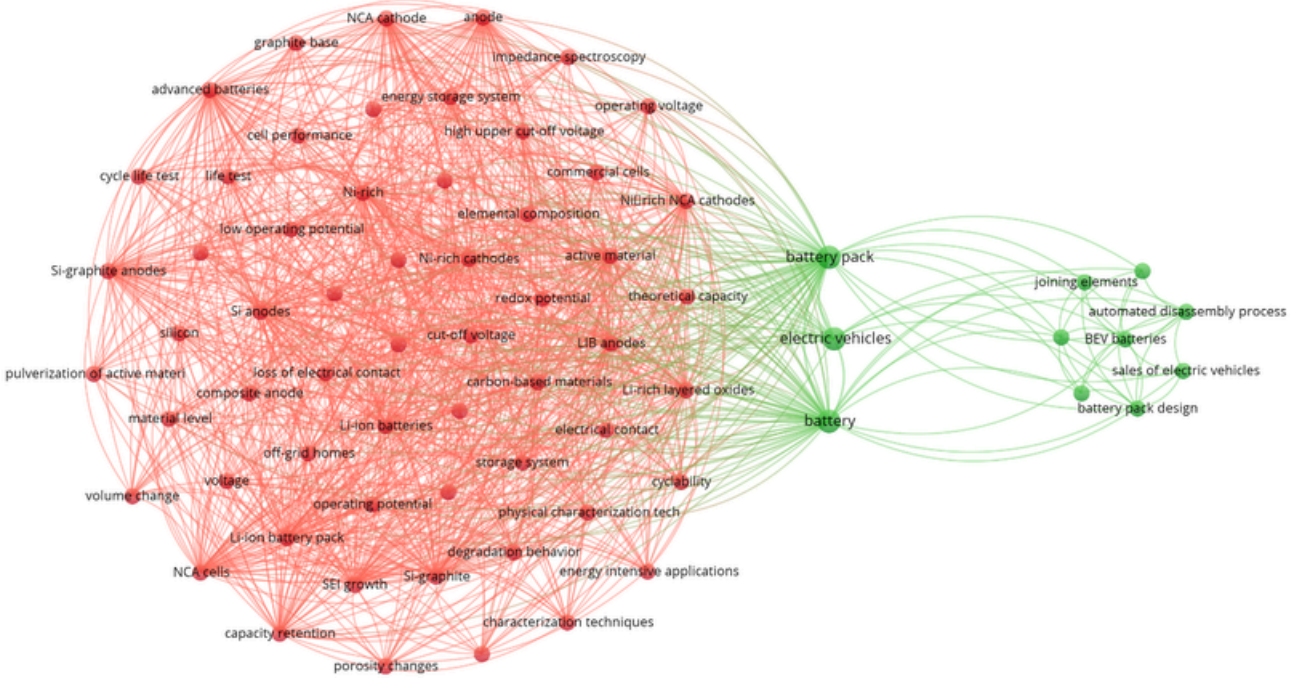

Figure 3: Co-occurrence network map for 250 concepts derived from titles and abstracts in the case study dataset using VOSviewer. Cluster 1:red, Cluster 2: green.