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Hard-to-Abate Literature Review

GIRA Hard-to-Abate Research Study
Gas Infrastructure Research Australia

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EXECUTIVE SUMMARY

This literature review was undertaken for Gas Infrastructure Research Australia to establish a clearer and more consistent understanding of what *hard-to-abate, hard-to-electrify*, or similar, means in the context of Australia's transition to net zero. While the term is increasingly used in policy, industry and low emissions planning, the literature shows there is no universally accepted definition, with different stakeholders applying it to different sectors, emissions sources and technologies depending on their objectives. This review was therefore conducted to build an evidence base of *hard-to-abate* applications and the factors considered to assign this terminology. This understanding could be used to support the development of a practical assessment framework for future implementation.

The review examined Australian and international literature from government agencies, policy organisations, research institutions, energy market bodies, academic publications and industry studies. Sources included OECD, IEA, DCCEEW, DISR, AEMO, CSIRO, Arup and GPA, providing perspectives from industrial decarbonisation, energy system planning, climate policy and practical implementation.

Table 1. Stakeholder perspectives on the application of the term *hard-to-abate*

	OECD	IEA	DCCEEW	Australian Government Department of Industry, Science and Resources	AEMO	CSIRO	ARUP	GPA
Industrial Decarbonisation	✓	✓		✓				
Energy System Planning					✓	✓		
Climate Policy	✓	✓	✓	✓				
Practical Implementation						✓	✓	✓

Key Findings

1. ***Hard-to-abate* is widely used but inconsistently defined.** While the term is most commonly associated with activities involving process emissions, feedstock requirements, high-temperature heat demands and some transport applications, no universally accepted definition exists. Its application varies between stakeholders and contexts, with the concept applied to different sectors, emissions sources and end uses depending on the purpose for which it is being used.
2. **Increasing policy significance, but no common assessment method.** Policymakers are increasingly using the concept to guide emissions reduction priorities, investment decisions and regulatory interventions. How *hard-to-abate* is defined can therefore influence where public and private investment is directed, which pathways are supported and, ultimately, the costs borne by customers and the broader economy. Despite this growing importance, no commonly adopted method exists for determining what should be classified as *hard-to-abate*.
3. **Abatement difficulty is technical, economic and practical, not simply a sector characteristic.** The literature more consistently identifies the *factors* that make abatement difficult than which *sectors* should carry the label. Technical feasibility, economic viability, and operational requirements are the most consistently cited considerations. Practical implementation factors, including operational requirements, infrastructure limitations, retrofit complexity, customer circumstances and the ability to implement change, materially influence progress towards net zero objectives.

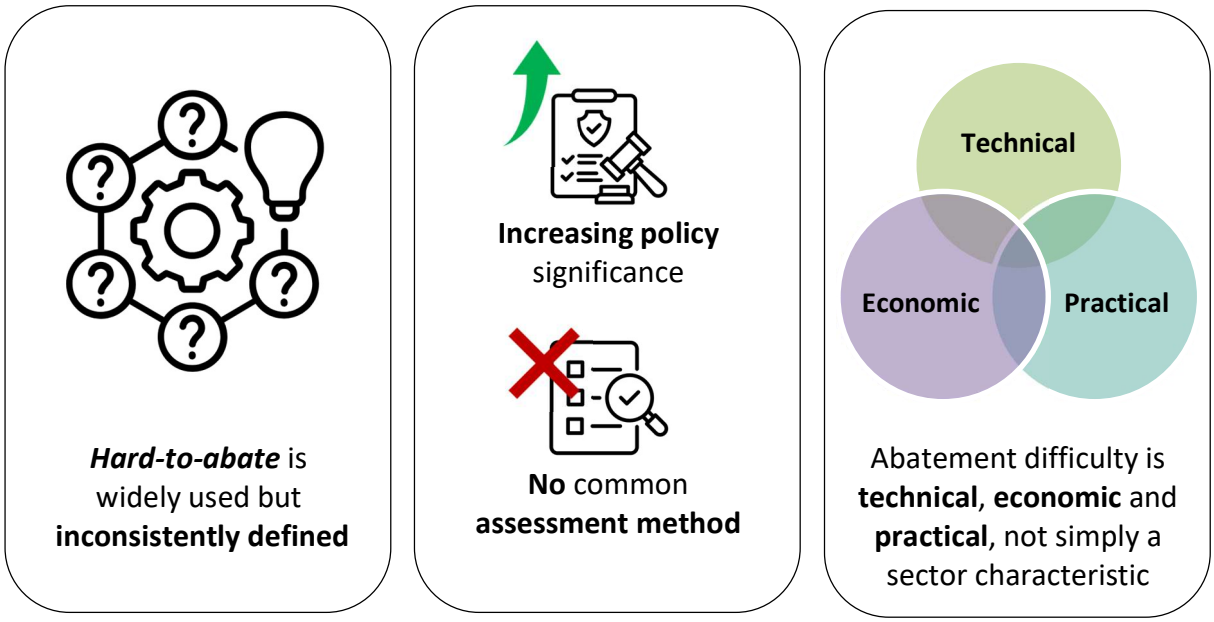

Figure 1. Key findings of the literature review

Taken together, the findings support a broader understanding of abatement difficulty than broad sector labels alone*.** Recent Australian studies identify examples including apartment buildings, heritage premises, homes requiring electrical supply, switchboard or wiring upgrades, hospitals, commercial kitchens, laundries and greenhouses, demonstrating how practical constraints can materially affect decarbonisation pathways. These examples suggest that assessment should focus on the circumstances of the particular end use, facility or customer. ***A technically available alternative does not, by itself, establish that an activity is readily abatable.

Recommendations

The review highlights a need for a more transparent and evidence-based approach to application of the term *hard-to-abate.* It recommends developing a transparent, multi-criteria framework that assesses specific emissions sources, processes or end uses against consistent technical, economic and practical criteria, rather than relying on broad sector labels. Such a framework should recognise that classifications are dynamic and likely to evolve as technologies, costs and infrastructure develop. This approach would support a more transparent and evidence-based application of the term in policy and planning.

Proposed next steps for GIRA would be to develop and test such an assessment framework against selected gas related end uses and examine their potential scale and materiality using available evidence.

CONTENTS

TABLE OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The transition to net zero emissions increasingly requires policymakers, industry participants and regulators to identify and prioritise emissions sources that are considered difficult to reduce or eliminate. In this context, the terms *hard-to-abate*, *hard-to-electrify*, and similar, have become widely used across policy, industry and research literature. The terms are commonly applied to industrial sectors such as steel, cement, chemicals, aviation and other activities where emissions reductions are considered more challenging than in sectors that can readily transition to renewable electricity or other low-emissions alternatives. However, despite its growing prominence, the literature indicates that there is no universally adopted definition of what constitutes a *hard-to-abate* sector, end use or emissions source. Instead, the term is often applied in different ways depending on the objectives of the stakeholder or target audience.

This review has been prepared to support the first component of the Gas Infrastructure Research Australia (GIRA) Hard-to-Abate Research Study. The purpose of the review is to examine how the term *hard-to-abate* is defined, interpreted and applied across Australian and international literature and to identify the factors commonly associated with abatement difficulty. The review also explores examples of sectors, activities and end uses that are frequently described as *hard-to-abate*, as well as the policy implications increasingly attached to the concept.

Literature reviewed includes reports and publications from governments, energy market bodies, industry organisations, research institutions and international policy organisations. These sources include, among others, the Department of Climate Change, Energy, the Environment and Water (DCCEEW), the Australian Energy Market Operator (AEMO), Commonwealth Scientific and Industrial Research Organisation (CSIRO), Arup, the International Energy Agency (IEA), the Organisation for Economic Co-operation and Development (OECD) and the Climate Club. Collectively, these stakeholders approach the concept of *hard-to-abate* from different perspectives, reflecting their various objectives in areas such as industrial competitiveness, emissions reduction, energy system planning, technology deployment, economic development and achievement of low emissions targets.

The review is intended to provide an evidence base for the development of a practical framework for assessing abatement difficulty. Rather than rely solely on broad sector-based classifications, such a framework could assess the characteristics that contribute to abatement challenges in specific contexts, including technical, economic, operational and infrastructure-related factors. By identifying common themes across the literature, the review aims to support a more transparent and evidence-based understanding of what makes an activity, sector or end use difficult to decarbonise, and how such assessments might be applied consistently across different applications.

2 DEFINING HARD-TO-ABATE AND RELATED TERMS

2.1 THE TERM 'HARD-TO-ABATE'

The term *hard-to-abate* is widely used throughout climate, energy and industrial net zero literature. Despite its prevalence, explicit definitions are relatively uncommon. Many sources apply the term to specific sectors, activities or emissions sources without clearly defining the threshold at which an activity becomes "*hard-to-abate*". Instead, the concept is often inferred through descriptions of the challenges associated with reducing emissions, including technical limitations, economic constraints, operational requirements or the absence of viable low-emissions alternatives.

Where explicit definitions are provided, they generally describe *hard-to-abate* activities as those for which emissions reductions are difficult to achieve using currently available or practical decarbonisation pathways. For example, the OECD and Climate Club describe *hard-to-abate* sectors as industrial sectors whose emissions are difficult to eliminate due to process emissions, high-temperature heat requirements, technological constraints and investment barriers (OECD/Climate Club, 2024). This definition is centred on industrial production and emphasises the characteristics that make the pursuit of net zero more challenging than in other sectors of the economy.

Similarly, DCCEEW defines *hard-to-abate* emissions as emissions that are difficult to reduce because of "how they are produced" or because "alternative ways of reducing emissions… [are not] available" (DCCEEW, 2026). The department notes that these emissions are often associated with industries where lower-emissions alternatives have not yet been developed or commercially deployed.

An academic perspective is provided by Max Åhman of Lund University, who's work examines the origins of the *hard-to-abate* concept and the factors that contribute to persistent emissions in energy intensive industries. Åhman (2020), describes *hard-to-abate* sectors as those that have historically remained outside the primary focus of efforts toward net zero due to the complexity of reducing emissions from industrial production processes. According to this perspective, sectors such as steel, cement and chemicals present unique challenges because emissions are often embedded within production processes rather than resulting solely from energy consumption.

While these definitions vary in emphasis, a common theme throughout the literature is that hard-to-abate activities are characterised by factors that make emissions reductions more challenging than in other sectors or end uses.

The types of factors considered relevant differ between stakeholders, reflecting their respective focus on issues such as industrial processes, technology deployment, economic viability, infrastructure, policy implementation and broader social or institutional considerations.

2.2 RELATED TERMINOLOGY

A range of related terms are used throughout the literature, often with overlapping meanings.

2.2.1 Hard-to-Electrify

The term *hard-to-electrify* frequently appears in studies examining electrification pathways and is often used interchangeably with *hard-to-abate*. However, the concepts are not identical. Hard-to-electrify generally refers to situations where direct electrification faces technical, economic or practical barriers, whereas *hard-to-abate* encompasses a broader range of emissions reduction challenges.

A recurring theme across electrification-focused studies is that the question is often not whether electrification is technically possible, but whether it is practical, affordable and capable of meeting operational requirements in a particular context. As Arup (2024) observes, "while technology options are available or in development…, electrification requires careful consideration of costs, infrastructure needs, and appliance types for specific situations". Similarly, GPA (2024) notes that "many factors that will influence the pathway and feasibility are location- or business-specific, and not directly related to the appliance, its function/purpose, or its capacity". Sources such as Arup and GPA therefore distinguish between technical feasibility and practical viability when assessing transition pathways. This distinction has important implications for the broader *hard-to-abate* discussion, as it suggests that abatement difficulty may arise from implementation challenges even where a technically feasible net zero pathway exists.

2.2.2 Energy-Intensive Industries

Academic literature often refers to energy-intensive industries (EIIs) when discussing *hard-to-abate* sectors. According to Åhman (2020), this category typically includes industries such as steel, cement, chemicals and other material-processing sectors that require significant energy inputs and often compete in international markets. The OECD defines EIIs as industries with “a higher-than-median energy input cost share over total inputs costs in the EU” (Dechezleprêtre et al., 2025). These industries feature prominently within *hard-to-abate* discussions due to their reliance on high-temperature heat, fossil feedstocks and long-lived capital assets. In many cases, emissions are generated not only through the consumption of energy but also through the chemical and material inputs required for production. This includes process emissions arising from industrial reactions, such as limestone calcination in cement manufacturing, and feedstock-related emissions, such as the use of coal in iron reduction or natural gas-derived hydrogen in ammonia production. As a result, EIIs feature prominently in *hard-to-abate* discussions because emissions are often inherent to both the energy systems and production processes upon which these industries have historically depended.

2.2.3 Carbon Lock-In

Another term closely associated with *hard-to-abate* sectors is ‘carbon lock-in’. Janipour et al. (2020) defines it as "a path-dependent process (...) whereby initial conditions, increasing economic returns to scale and social and individual dynamics act to inhibit innovation and competitiveness of low-carbon alternatives". Åhman (2020) describes this phenomenon as arising from highly efficient but fossil-fuel-dependent production systems that have developed over many decades. Existing infrastructure, supply chains, production processes and investment cycles can make rapid transitions to low-emissions alternatives difficult, even where alternative technologies are technically feasible.

2.2.4 Carbon Leakage

The concept of carbon leakage also appears frequently in literature relating to *hard-to-abate* industries. Carbon leakage refers to the relocation of production to jurisdictions with less stringent climate policies, potentially reducing the effectiveness of emissions reduction measures while affecting industrial competitiveness (Åhman, 2020). This concern has been particularly influential in policy discussions relating to emissions-intensive trade-exposed industries and has informed proposals such as carbon border adjustment mechanisms, sectoral agreements and Climate Club approaches.

2.3 STAKEHOLDER PERSPECTIVES

A review of the literature suggests that stakeholders generally define and apply the concept of *hard-to-abate* in ways that reflect their organisational objectives and policy priorities. One point of variation between stakeholders is the "unit of assessment", being whether the concept is applied to sectors, emissions sources, industries, facilities, processes or individual end uses.

International policy organisations such as the OECD, and IEA primarily use the term to identify industrial sectors where emissions reductions are difficult due to process emissions, feedstock requirements, high-temperature heat demands and investment barriers (OECD/Climate Club, 2024; IEA, 2020). In this context, *hard-to-abate* functions as a policy category used to identify sectors that may require targeted support, international cooperation or specialised net zero pathways. The primary unit of assessment is typically the sector or industry.

Australian Government publications increasingly conceptualise *hard-to-abate* emissions in terms of the availability, maturity and feasibility of decarbonisation options rather than as a characteristic of particular industries. Government stakeholders tend to focus more directly on emissions reduction outcomes than on sector classifications, applying the concept to emissions, processes and functions for which practical alternatives remain limited, immature, uneconomic or unavailable (DCCEEW, 2025a; DCCEEW, 2025b; DCCEEW, 2026; DISR, 2024). This framing encompasses activities such as high-temperature industrial processes, chemical feedstocks, aviation and other applications where electrification or direct substitution may not yet be feasible. Across these documents, *hard-to-abate* is therefore used less as a fixed sectoral label and more as a way of identifying specific emissions sources and activities that face persistent decarbonisation constraints, shifting the unit of assessment from sectors towards emissions and their associated functions. Energy system planners such as AEMO generally use the term in the context of economy-wide transition planning (AEMO, 2026). References to *hard-to-abate* sectors in planning documents are typically associated with assumptions regarding future fuel use, industrial demand, hydrogen adoption and the ongoing role of alternative decarbonisation pathways.

Engineering and advisory consultancies, research organisations and industry-focused studies frequently approach the concept from a more practical perspective. Sources such as Arup, CSIRO, GPA and industry electrification studies tend to focus less on whether a sector is inherently *hard-to-abate* and more on the specific factors that affect decarbonisation outcomes in individual circumstances (Arup, 2024; Graham et al., 2023; GPA, 2024). These sources commonly identify operational requirements, infrastructure availability, financial constraints, ownership arrangements, site characteristics and implementation challenges as factors influencing abatement difficulty. This demonstrates cases where the unit of assessment is no longer the sector itself, but a particular process, facility, building or end use.

The variation in stakeholder perspectives is also reflected in the sectors that are ultimately classified as *hard-to-abate*. Reviewing definitions used across scientific publications, government policy, international institutions and industry communications, Dufour-Décieux et al. (2025) found considerable

variation in the sectors and emissions sources assigned the label, as shown in Figure 2. While sectors such as iron and steel, cement, aviation and shipping were commonly identified across stakeholder groups, there was substantially less agreement regarding other sectors and emissions sources. The finding suggests that, despite widespread use of the term, stakeholders do not apply a consistent classification framework and often define *hard-to-abate* according to their own policy, industry or analytical objectives.

Taken together, these perspectives suggest that *hard-to-abate* is less a single technical definition and more a policy and analytical concept that is applied to different decarbonisation challenges. While stakeholders generally agree that the term relates to activities facing greater barriers to emissions reduction, they often differ in the unit of assessment used to apply the concept, with classifications variously focused on sectors, emissions sources, technologies, facilities or end uses. These differences frequently reflect the stakeholder's underlying objective, whether that be industrial transformation, emissions management, energy system planning or practical implementation of decarbonisation measures.

Different Definitions of Hard-to-Abate

Sectors/Emissions \ Sources		Research		Policy		Institutions		Industry	
		[2]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Industry	Iron and steel	●	●	●	●	●	●	●	●
	Cement	●	●	●	●	●		●	●
	Chemicals			●	●	●	●	●	
	Aluminium			●	●	●			
	Green hydrogen								●
	Refining/Oil				●	●	●	●	
	Liquefied NG/Gas			●	●	●	●		
Transport	Trucking	●	●	●		●	●		●
	Aviation	●	●	●		●	●		●
	Shipping	●	●	●		●	●		●
	Agriculture	●	●	●					
Energy	Highly reliable electricity	●	●						
	Power			●				●	
	Heating and cooling	●							●

Figure 2. Comparing stakeholder definitions of *hard-to-abate* sectors (Dufour-Décieux et al., 2025) – see Dufour-Décieux et al. (2025) for additionally referenced sources

2.4 SECTORS AND END USES COMMONLY ASSOCIATED WITH ABATEMENT DIFFICULTY

2.4.1 Traditionally *Hard-to-abate* Sectors

Across the literature, the term *hard-to-abate* is most commonly applied to EII sectors, including steel, iron, cement, chemicals, petroleum refining, mining and other forms of heavy manufacturing (Åhman, 2020; OECD/Climate Club, 2024; AEMO, 2026). Australian studies identify a similar group of industries, including glass, lime, plaster, ceramics, pulp and paper production, and other materials-processing activities (GPA, 2025; Frontier Economics, 2020). International sources also frequently identify aviation and shipping as *hard-to-abate* sectors due to the challenges associated with decarbonising long-distance transport (IEA, 2020).

While the specific sectors identified vary between sources, there is a high degree of consistency regarding the types of activities commonly associated with the term. Heavy industry and transport applications dominate *hard-to-abate* classifications across international policy, industry and academic literature (Åhman, 2020; OECD/Climate Club, 2024; IEA, 2020).

2.4.2 Applications Commonly Considered More Readily Abatable

In contrast, several activities are commonly identified as having established decarbonisation pathways. At a broad sector or technology level, common examples include residential and commercial building services, space and water heating, cooking, passenger vehicles, buses and many lower-temperature heating applications (Beyond Zero Emissions (BZE), 2022; AEMO, 2026).

A common characteristic of these applications is the availability of commercially mature alternatives. The Energy Efficiency Council (EEC) and Property Council of Australia (PCA) (2026), for example, note that technologies capable of reducing emissions from the built environment are already available for immediate deployment. Similarly, BZE (2022) identifies buildings, passenger vehicles and many industrial heating applications as sectors where existing technologies can achieve substantial emissions reductions today.

These sources reflect the broad characterisation of these applications as more readily abatable. Section 2.4.3 considers how that characterisation can vary when practical implementation factors are taken into account.

2.4.3 Emerging Applications and Evolving Interpretations of *Hard-to-abate*

While *hard-to-abate* discussions have traditionally focused on heavy industry, several recent Australian studies have highlighted a growing group of applications that do not fit neatly within heavy industrial or readily electrifiable decarbonisation categories. Examples include apartment buildings, heritage premises, commercial laundries, hospitals, hotels, aquatic centres, commercial kitchens, coffee roasters, greenhouses and certain medical facilities (GPA, 2025; EEC & PCA, 2026).

These applications are not typically characterised by process emissions, fossil feedstocks or significant temperature requirements. Instead, the challenges identified relate more often to infrastructure, retrofit complexity, operational requirements and site or customer circumstances. This suggests that abatement difficulty can arise at the level of a particular end use, facility, or customer, even where the broader sector is generally considered more readily abatable. It shifts the focus from which sectors are *hard-to-abate* to where abatement difficulties occur in practice.

2.5 HOW IT IS USED IN POLICY AND REGULATION

The literature suggests that the term *hard-to-abate* has evolved beyond a simple description of technological difficulty and is increasingly being used as a policy concept to guide net zero target priorities, investment decisions and regulatory interventions. Consequently, the way *hard-to-abate* activities or emissions are defined carries significant practical implications, shaping investment flows, technology pathways and the allocation of transition costs across sectors and end users. However, there is no widely accepted definition, and stakeholders apply the concept using different units of assessment, sectoral boundaries and analytical frameworks (Dufour-Décieux et al., 2025) depending on the policy objective being pursued.

International organisations such as the OECD/Climate Club and the International Renewable Energy Agency (IRENA) primarily apply the term to emissions-intensive industrial and transport sectors, including steel, cement, chemicals, shipping and aviation (OECD/Climate Club, 2024; IRENA, 2024). Within this context, *hard-to-abate* functions as a policy category used to identify sectors facing technological, commercial and investment barriers to deep decarbonisation and therefore requiring targeted support, international co-operation and dedicated transition pathways. The primary concern is how governments and institutions can accelerate the transformation of EIIs while maintaining industrial competitiveness and supporting economic development, particularly within globally traded markets (OECD/Climate Club, 2024; IRENA, 2024).

This perspective is also reflected in the way international organisations describe *hard-to-abate* sectors. For example, IRENA refers to sectors that are "more complex and costlier to decarbonise" due to "technological limitations, economic and geopolitical concerns and these sectors' extensive demand for energy" (IRENA, 2024). Under this framing, classification is closely linked to sector-wide transformation challenges and the deployment of new technologies, fuels, infrastructure and supply chains.

By contrast, within policy and regulatory frameworks, the concept of *hard-to-abate* is used to distinguish emissions that may remain after readily available decarbonisation measures have been deployed and therefore require additional policy attention. Both the Australia's Net Zero Plan and the Electricity and Energy Sector Plan define *hard-to-abate* emissions as "emissions from essential processes and products with no near-term decarbonisation options" (DCCEEW, 2025a; DCCEEW, 2025b). Similarly, the Future Gas Strategy identifies ongoing demand for gas in "higher-value and non-substitutable" applications where commercially viable alternatives remain limited or unavailable (DISR, 2024). In practice, these frameworks generally assume that electrification and other lower-cost abatement opportunities should be pursued first, with *hard-to-abate* emissions representing the residual emissions that may require low-carbon fuels, carbon capture and storage, carbon removal or other emerging mitigation approaches to achieve net-zero outcomes (DCCEEW, 2025a; DCCEEW, 2025b; DCCEEW, 2026; DISR, 2024). The primary concern is therefore not which sectors are difficult to decarbonise, but which emissions are likely to persist despite broader economy-wide net zero target efforts, shifting the unit of assessment from sectors to residual emissions sources.

Recent academic literature has also highlighted the variability in how the term is applied across stakeholder groups. Dufour-Décieux et al. (2025) observe that policymakers, researchers and industry organisations often apply the term to different sectors and emissions sources, despite the absence of a commonly accepted definition. The authors note, for example, that policy documents may refer to *hard-to-abate* sectors without explicitly defining which sectors are included or the net zero pathways envisaged for them (Dufour-Décieux et al., 2025). In response, they propose that *hard-to-abate* classifications should focus on emissions rather than sectors, arguing that…

"… while a sector encompasses various emission sources, not all emissions within it are equally challenging to mitigate" (Dufour-Décieux et al., 2025).

This represents a further shift in the unit of assessment, from broad sector-level classifications towards individual emissions sources.

These perspectives may be complementary, but they are not interchangeable; they answer different questions and can produce different classifications and policy outcomes. The OECD/Climate Club and IRENA framing focuses on where *hard-to-abate* emissions are concentrated within the economy and seeks to identify sectors requiring additional policy support (OECD/Climate Club, 2024; IRENA, 2024). By contrast, the Australian Government framing focuses on the nature of emissions that remain once conventional abatement options have been exhausted and seeks to identify what additional interventions may be required to achieve low emissions outcomes (DCCEEW, 2026). Together, they suggest that *hard-to-abate* is both an industrial transformation challenge and a residual emissions challenge, depending on whether the unit of assessment is the sector or the emissions source.

3 ASSIGNING THE CLASSIFICATION 'HARD-TO-ABATE'

The literature assessed reveals no single method for determining whether a sector, activity or end use should be classified as *hard-to-abate*. However, despite variation in terminology and application, there is a notable degree of consistency regarding the factors that stakeholders consider when assessing abatement difficulty. While some factors appear almost universally across the literature, others emerge primarily within particular stakeholder groups or contexts. This distinction provides insight into both how the concept is currently being applied and the challenges associated with developing a consistent classification framework.

3.1 AREAS OF BROAD AGREEMENT

Despite differences in how *hard-to-abate* is defined, the literature demonstrates three broad, interrelated areas of agreement regarding the factors that contribute to abatement difficulty: technical feasibility, economic feasibility and practical deployment considerations.

The strongest area of agreement concerns the role of technical constraints. Across work by international organisations, governments, industry groups, and engineering and advisory consultants, activities are commonly described as *hard-to-abate* where emissions are closely linked to the underlying production process or where existing technologies are unable to readily provide an equivalent low-emissions alternative. Examples repeatedly cited include industrial process emissions, fossil-derived feedstocks, high-temperature heat requirements and applications where combustion itself is integral to the outcome being produced (IEA, 2020; OECD/Climate Club, 2024; DCCEEW, 2026; GPA, 2024). Åhman (2020) similarly notes that in many EIIs, "fossil energy and fossil feedstock is deeply embedded in the production process", meaning that emissions reductions often require fundamental changes to the production process itself rather than simply changing energy sources.

A second area of broad agreement relates to economic considerations. Studies by international policy organisations, academic researchers, engineering and advisory consultancies, and industry-focused groups all recognise that abatement difficulty is influenced not only by technical feasibility, but also by whether alternative pathways are economically achievable. References to capital costs, operating costs, investment cycles, infrastructure expenditure and competitiveness impacts appear across academic, policy and industry literature (Åhman, 2020; Arup, 2024; GPA, 2025). In many cases, emissions reduction pathways are recognised as technically possible, yet still described as difficult due to the scale of investment required or the timing of major asset replacement decisions. For example, Åhman (2020) notes that major reinvestment opportunities in many industrial facilities may only occur every 15 to 25 years, creating limited opportunities to introduce low-emissions technologies.

A third area of agreement concerns practical deployment challenges, which often arise from the interaction of technical and economic factors rather than either factor in isolation. For example, a technology may exist in principle but still be regarded as difficult to deploy where it is immature, prohibitively expensive, or unable to satisfy key process requirements (Arup, 2024; OECD/Climate Club, 2024).

As a result, assessments of abatement difficulty frequently extend beyond questions of technological availability to consider whether solutions can be implemented effectively and at scale within real-world operational, commercial and infrastructure constraints.

3.2 EMERGING AND CONTEXT-DEPENDENT CONSIDERATIONS

Greater variation emerges when stakeholders move beyond broad industrial classifications and begin assessing specific facilities, customers or end uses.

At this more granular level, the existence of a technically available alternative does not necessarily determine how readily it can be implemented.

Recent studies, particularly those examining electrification pathways, place significantly greater emphasis on infrastructure, implementation and site-specific circumstances than traditional *hard-to-abate* literature. Sources such as Arup (2024), GPA (2024) and CSIRO (Graham et al., 2023) identify factors such as existing infrastructure, retrofit complexity, space limitations, access to electricity networks, shared building services and geographic location as potentially influencing abatement difficulty. This is consistent with GPA (2025), who notes that "each household and business faces a range of complexities when assessing the best solution for their energy needs", and that "the availability of electric energy alternatives does not guarantee suitability for all residents or businesses". Together, these observations highlight that abatement difficulty is increasingly understood not simply as a function of technology availability, but as a product of how technologies interact with the specific technical, infrastructural, operational and decision-making circumstances of individual sites and users.

The Victorian Building Electrification Regulatory Impact Statement (RIS) estimates that 19% of Victorian homes would incur $2,525 to $12,250 in connection upgrade costs, averaging $4,700 (Victorian Government, 2024). This excludes any switchboard and household wiring costs beyond a basic or standard connection service upgrade, which the RIS acknowledges may also be required but were not quantified in the cost benefit analysis.

These studies also introduce considerations that are largely absent from international industry-focused definitions. While traditional *hard-to-abate* literature tends to focus on the characteristics of technologies, more recent studies place greater emphasis on the circumstances of the end user. Ownership arrangements, heritage listings, rental status, customer control over assets, apartment governance structures and access to capital are all identified as factors that may materially influence the practical ability to achieve net zero outcomes within a particular end use (Graham et al., 2023; GPA, 2025). Customer choice and preferences can also influence which transition pathway is adopted and when, particularly where alternatives differ in cost, performance, amenity or disruption (GPA, 2024; Horizon Power, 2023).

Notably, these factors do not determine whether a low-emissions technology exists, but rather whether it can realistically be adopted in a specific context.

This suggests that, for some stakeholders, abatement difficulty is shaped not only by technical constraints but also by who is responsible for funding and implementing the transition.

This theme is reflected in CSIRO's observation that "the ability to access household savings depends on the amount of control a customer has over their housing" and that electrification pathways can differ significantly between owner-occupiers, renters and residents of apartment buildings (Graham et al.,

2023). The Victorian Parliament's 2026 inquiry found that apartment residents and owners corporations can face limited control over investment decisions, constrained budgets and costly feasibility requirements, alongside technical barriers such as outdated wiring, switchboards and complex retrofits (Legislative Assembly Environment and Planning Committee, 2026).

A similar distinction emerges in relation to operational requirements. While heavy-industry literature often focuses on the technical characteristics of emissions sources, engineering and implementation-focused studies give greater attention to whether alternative technologies can operate effectively within existing processes and operating conditions. Production schedules, reliability requirements and integration with existing systems are frequently identified as factors influencing the practicality of implementing net zero pathways (Åhman, 2020; Arup, 2024).

The result is a broader understanding of abatement difficulty. Rather than asking solely whether emissions can be reduced from a technical and economic perspective, these sources ask whether emissions can be reduced in practice given the constraints faced by specific users, facilities or industrial processes. Technical availability and practical achievability are therefore distinct, but related, considerations.

3.3 KEY OBSERVATIONS

A review of the literature suggests that stakeholders are generally more aligned on the factors that contribute to abatement difficulty than they are on the sectors that should be classified as *hard-to-abate*. Technical feasibility, economic viability and the availability of suitable alternatives emerge as the most consistently cited considerations across stakeholder groups. More recent electrification and transition focused studies broaden this assessment to include practical factors such as infrastructure compatibility, retrofit complexity, ownership arrangements, customer control, affordability and implementation challenges.

This distinction appears to reflect differing stakeholder objectives. Sources focused on industrial decarbonisation and climate policy tend to adopt sector-based units of assessment, emphasising the characteristics of sectors and technologies, whereas sources focused on implementation tend to place greater weight on the practical circumstances required for net zero targets to be achieved. This can produce different conclusions depending on whether the assessment is made at the sector, end use, facility or customer level.

Together, these perspectives suggest that abatement difficulty is rarely attributable to a single factor and is more commonly the result of multiple interacting technical, economic and practical considerations. The availability of a technically viable alternative does not, by itself, establish that an activity is readily abatable in practice.

4 KEY CONCLUSIONS

4.1 HARD-TO-ABATE IS WIDELY USED, BUT INCONSISTENTLY DEFINED

- The term *hard-to-abate* is widely used across policy, industry and research literature; however, there is no universally accepted definition. Stakeholders apply the concept to different units of assessment, including sectors, emissions sources, technologies, processes and end uses.
- The literature identifies two broad interpretations of *hard-to-abate*. Industrial decarbonisation and climate policy literature typically focuses on emissions that are difficult to eliminate due to technical limitations or the absence of mature alternatives, whereas electrification and implementation-focused studies assess the practical difficulty of transitioning specific facilities, end uses or customer groups.
- When comparing sector-based classifications against activity-based assessment, much of the literature classifies entire sectors (e.g. steel, cement and chemicals) as *hard-to-abate*. However, other studies identify abatement challenges at the level of specific facilities, processes or end uses, including applications such as apartment buildings, heritage listings, hospitals and commercial laundries. This suggests that the choice of unit of assessment may significantly influence what is ultimately classified as *hard-to-abate* and that sector-wide classifications may not always capture the practical factors influencing abatement difficulty in individual circumstances.

4.2 HARD-TO-ABATE IS INCREASINGLY IMPORTANT IN POLICY AND PLANNING, BUT LACKS A COMMON ASSESSMENT METHODOLOGY

- Policy makers are increasingly attaching policy significance to the concept of *hard-to-abate* emissions, including in discussions relating to industrial decarbonisation, carbon management technologies and the future role of alternative energy pathways. Despite this growing importance, there is no commonly adopted method for determining what should be classified as *hard-to-abate*.
- The way *hard-to-abate* is defined can have significant policy implications. Sector-based approaches may assist with broad policy design, industry planning and investment prioritisation, while emissions-based approaches can provide a more granular understanding of where challenges in reaching net zero arise within sectors.

4.3 ABATEMENT DIFFICULTY IS TECHNICAL, ECONOMIC AND PRACTICAL, NOT SIMPLY A SECTOR CHARACTERISTIC

- The literature is generally more consistent regarding the factors that contribute to abatement difficulty than the sectors that should be classified as *hard-to-abate*. Technical feasibility, economic viability, operational requirements and the availability of suitable alternatives emerge as the most widely recognised considerations.
- Traditional *hard-to-abate* classifications are most commonly associated with EIIs and transport applications where process emissions, feedstock requirements or high-temperature heat demands create significant decarbonisation challenges. More recent studies indicate that abatement difficulty may also arise from practical implementation challenges, including infrastructure constraints, ownership arrangements, governance structures, retrofit complexity and site-specific circumstances.

- Collectively, the literature suggests that abatement difficulty is best understood as the result of interacting technical, economic and practical factors rather than an inherent characteristic of a particular sector. The availability of a technically viable alternative does not, by itself, establish that an activity is readily abatable in practice. As technologies, costs and infrastructure evolve, classifications are likely to change over time and should not be treated as fixed categories.

5 RECOMMENDATIONS

5.1 MAKE CLASSIFICATION TRANSPARENT AND EVIDENCE BASED

The literature review identified a wide range of related terms, including *hard-to-electrify*, *energy-intensive industries*, *carbon lock-in* and *carbon leakage*, which are often used with varying levels of definition and consistency. Future research or discussion about *hard-to-abate* should clearly define and explain all terminology being applied, including the relationship between different concepts, where appropriate.

Where "hard-to-abate" is used to influence policy and regulatory interventions that direct public and private investment, the basis for the classification should be transparent and evidence-based.

This would support greater alignment across policy, industry and research discussions, reduce ambiguity in the application of classifications and improve transparency regarding what is being assessed and why.

5.2 ESTABLISH A TRANSPARENT HARD-TO-ABATE ASSESSMENT FRAMEWORK

The literature review revealed significant variation and effectiveness in how *hard-to-abate* is assessed when stakeholders adopt different units of assessment, apply different classification approaches and emphasise different contributing factors.

An assessment framework that clearly defines both the unit of assessment and the factors being assessed as *hard-to-abate* should be developed. Such a framework should also recognise that classifications may change over time as technologies, costs and supporting infrastructure evolve.

5.2.1 Recommended Units of Assessment

The literature review identified several different ways in which *hard-to-abate* classifications are currently applied. Future assessment approaches should explicitly define the unit or units of assessment prior to applying any classification, as different units are designed to answer different questions and may produce different outcomes.

Potential units of assessment, their advantages and limitations, are summarised in Table 2.

Table 2. Units of assessment comparison

Unit of assessment	Advantages	Limitations
Sector	Simple, widely understood, aligns with many policy discussions	May overlook variation within sectors and over-classify some activities
Emissions source	Aligns with DCCEEW and residual-emissions frameworks; focuses on the emissions themselves	May overlook practical implementation barriers affecting abatement outcomes
Process or end use	Captures the specific activity creating emissions; allows comparison across sectors	Can become more complex and data intensive
Facility or site	Reflects real-world operational constraints and infrastructure requirements	Site-specific factors may reduce consistency between assessments
Customer or archetype	Captures ownership, governance, financial and implementation barriers	Results may be difficult to generalise across broader sectors

The literature review also identified the two dominant approaches to classifying *hard-to-abate* activities, being sector-based and emissions-based classifications.

Sector-based classifications are simple, widely understood and useful for policy communication, but may overlook variation within sectors. Emissions-based classifications focus directly on the emissions requiring abatement and align closely with low emissions planning but may not fully account for practical implementation barriers such as infrastructure constraints, ownership arrangements or site-specific challenges.

An assessment framework could seek to combine the strengths of both sector- and emission-based approaches, using sectors as a useful organising structure while determining hard-to-abate through the assessment of specific emissions sources, processes or end uses against a consistent set of criteria, with classifications periodically reassessed as technologies, costs and implementation conditions evolve.

This combined approach would result in more meaningful and transparent assessment of *hard-to-abate* regardless of the sector being assessed.

5.2.2 Recommended Multi-Factor Assessment Methodology

Given the multidimensional nature of abatement difficulty, future assessment approaches should evaluate activities against a consistent set of criteria, recognising that *hard-to-abate* status is determined by the characteristics of a specific activity rather than the sector in which it occurs. Potential assessment factors identified through the literature review, and that could be considered in a multi-factor assessment methodology, include:

- **Technical Feasibility**
  Whether technically viable net zero pathways exist, including consideration of process emissions, feedstock requirements, temperature requirements, technology maturity and performance requirements.
- **Economic Viability**
  The cost and financial implications of pursuing net zero, including upfront capital costs, operating costs, asset replacement cycles and broader competitiveness considerations.
- **Practical Feasibility**
  The extent to which technically and economically viable pathways can be implemented in practice, including operational, infrastructure, implementation and decision-making considerations.
    - **Operational Requirements**
      The extent to which alternative technologies can meet operational requirements relating to reliability, continuity of supply, product quality and process integration.
    - **Infrastructure Requirements**
      The availability and suitability of supporting infrastructure, including electricity networks, fuel supply systems, space requirements and site-specific physical constraints.
    - **Implementation Complexity**
      Practical barriers affecting deployment, including retrofitting challenges, equipment availability, skills requirements, planning approvals and transition timelines.
    - **Customer and Decision-Making Constraints**
      Factors affecting the ability to implement change, including ownership arrangements, tenancy structures, shared infrastructure and governance requirements, customer control over assets and the cost or disruption associated with available pathways.

By focusing on the range of factors that influence abatement difficulty, rather than relying solely on broad sector classifications, future assessments can support a more transparent and practical understanding of the degree of abatement difficulty associated with a particular activity, emissions source or end use.

To test this approach, a logical next step for GIRA would be to develop and trial such an assessment framework against selected gas related end uses and examine their potential scale and materiality using available evidence. If necessary, future assessment frameworks could be established and tested for a range of notionally *hard-to-abate* sectors, recognising the bespoke nature of the abatement needs of each.

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