Challenges and Considerations for Hydrogen Integration in Natural Gas Pipeline Networks: A Comparative Screening Methodology

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1 ABSTRACT

As part of the global imperative to decarbonise fuel, repurposing existing natural gas pipeline infrastructure for hydrogen is considered an essential and expedient pathway, particularly for industrial heat and energy applications. However, this transition presents technical and operational challenges, requiring a structured approach to assess pipeline feasibility. This paper presents a methodology developed to screen pipelines for hydrogen repurposing through a structured process. The methodology evaluates key factors such as coating condition, material test certificate availability, welding records, encroachment, burial depth, block valve suitability, and environmental considerations.

To demonstrate the application of this screening methodology, two case studies are outlined: Case A examines an older pipeline system with limited material records and legacy design considerations, while Case B focuses on a newer system built to more modern standards. The results of these assessments highlight the key challenges, risks, and mitigation strategies identified through the screening process. Insights from this work provide a structured approach for pipeline operators and stakeholders to make informed decisions on hydrogen conversion, ensuring safety, reliability, and efficiency in the transition to hydrogen-based energy systems.

2 INTRODUCTION

Fossil fuels are the primary energy source, accounting for 80% of global primary energy consumption in 2023 [1]. Scientific consensus correlates this reliance on fossil fuels and the slow development of renewable energy infrastructure with a cascade of adverse effects due to human-generated greenhouse gas emissions. Since the early 1800s, sea levels have risen approximately 20 cm [2], and between 2011 and 2020, global surface temperatures increased by 1.1 °C compared to levels recorded between 1800 and 1900 [3]. As a result, the Earth has experienced more frequent and severe weather events, damage to ecosystems, loss of biodiversity, and reduced food security. A critical strategy to mitigate further climate impacts is to balance greenhouse gas emissions with removals from the atmosphere - a target commonly referred to as "net-zero."

The UK government, through the Climate Change Act of 2008 [4], has committed to achieving net-zero greenhouse gas emissions by 2050, with a key milestone of decarbonizing the energy sector by 2035. Globally, energy production accounts for over 75% of emissions, making the transition to low-carbon alternatives essential. Hydrogen has emerged as a promising energy vector due to its high specific energy density and low emissions. It can be generated through electrolysis of water (green hydrogen) or steam methane reforming with carbon capture (blue hydrogen), as shown in Equations 1-1, 1-2. A secondary reaction, the Water Gas Shift (WGS), involving carbon monoxide further generates H_2, Equation 1-3.

$$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$$ **Equation 1-1**

$$CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2(g)}$$ **Equation 1-2**

$$CO_{(g)} + H_2O_{(g)}\ CO_{2(g)} + H_{2(g)}$$ **Equation 1-3**

A critical aspect of scaling hydrogen deployment is the development of efficient transportation infrastructure. Repurposing existing natural gas pipelines for hydrogen has gained significant attention as a potentially cost-effective and highly expedient solution. However, the suitability of these pipelines varies.

Given the scale of planned hydrogen infrastructure projects, such as the European Hydrogen Backbone (EHB) [5] - which envisions approximately 53,000 km of hydrogen pipelines across Europe by 2040, with 60% repurposed from existing natural gas infrastructure and 40% newly built - there is an urgent need for an efficient method to determine which pipelines are viable candidates for conversion. This paper presents a structured screening assessment designed to expedite the evaluation process by identifying pipelines that warrant detailed feasibility studies and those that may be unsuitable for repurposing.

To illustrate the methodology, two case studies are examined: Case A evaluates an older pipeline system with limited material records and legacy design considerations, while Case B assesses a newer system built to modern standards. The proposed screening methodology provides pipeline operators and stakeholders with a structured approach to make informed decisions on the feasibility of hydrogen conversion for their systems.

3 Methodology

This model is designed as a high-level screening assessment to evaluate the suitability of existing natural gas pipelines for hydrogen repurposing, considering several key parameters to provide an initial indication of feasibility. The methodology utilises a rating (1 to 10) and cost-based weighting system to determine the suitability of the pipeline for hydrogen repurposing based on the Kepner-Tregoe method. [6] Each parameter is assigned a rating and weighting that reflects the typical costs of addressing that parameter, such as maintenance, testing, or material replacement. In isolation, each parameter will not significantly influence the decision to repurpose. However, the multiplication of the associated rating and weighting indicates how well the pipeline meets the required criteria for repurposing. This methodology enables users to efficiently identify assets suitable for more detailed assessment and investment decisions.

3.1 Coating Condition

Repurposing implies a significant life extension; the condition and suitability of a pipeline's external coating play a critical role in determining its suitability for hydrogen repurposing. Coatings are the primary barrier against external corrosion, their degradation over time can significantly impact the integrity of a pipeline. Many older pipelines are coated with materials such as coal tar enamel, asphalt enamel, or polyethylene tapes, which may have deteriorated, leading to cracking, disbondment, or increased permeability. In contrast, modern fusion-bonded epoxy (FBE) and 3-layer coatings offer superior adhesion and resistance to degradation.

In cases where coating failure has occurred, reliance on cathodic protection (CP) systems increases – potentially increasing current demand to an unmanageable level. Furthermore, coating disbondment can create shielding effects, preventing CP from effectively mitigating corrosion, thus elevating the risk of loss of integrity by wall loss through corrosion. To determine if a coating requires repair, it is important to look at existing DCVG and CIPS data for indications of current drains or dig records for visible inspections and UT results for signs of corrosion at defects.

The environmental impact and expenditure a full-scale recoat would demand would make the process expensive and disruptive, therefore, the extent and severity of the coating degradation and suitability for continued service with limited repairs must be factored.

3.2 PIPELINE CONDITION

Hydrogen induced degradation can occur with various common pipeline defects. However, the most critical are "hard spots", defects such as cracks and dents, which are highly susceptible to hydrogen embrittlement.

Cracks are a primary concern, as hydrogen significantly accelerates fatigue crack growth rates (FCGR) and reduces fracture toughness. Pipelines with known cracks may be unsuitable for repurposing unless mitigated through repairs or operating pressure reductions. For unknown cracks, confidence in integrity can be improved with historic hydrotest data (demonstrating resistance to crack propagation) and cyclic pressure history (indicating past fatigue loading conditions). However, if future operation involves significant pressure cycling, hydrogen-assisted fatigue could still drive crack propagation, reducing pipeline life. Crack detection requires specialist in-line inspection (ILI) tools, including transverse magnetic flux leakage (MFL-T), angle probes, and electromagnetic acoustic transducers (EMAT). These tools provide varying levels of sensitivity, with EMAT showing strong Probability of Detection (POD), but weak Probability of Identification (POI). [7, 8] All these inspection methods are expensive and may necessitate multiple runs to validate results.

Dents are assessed based on plastic strain criteria, as per API RP 1183. [9] In natural gas service, dents are typically accepted based on a strain threshold linked to the material’s strain-to-failure in tensile tests. However, in hydrogen service, ductility is reduced, meaning strain limits must be lowered. Dents that were previously acceptable may now require strain-based assessment and potential repair to prevent hydrogen-induced failure.

3.3 MATERIAL RECORDS

The availability and quality of material test data from mill certificates are critical factors in determining a pipeline’s feasibility for hydrogen repurposing. Older pipelines often lack comprehensive documentation regarding material properties, manufacturing specifications, and historical modifications. The absence of such data introduces significant uncertainty into integrity assessments, potentially necessitating conservative assumptions or extensive verification testing.

One of the primary concerns is identifying the pipeline and weld metals' mechanical properties, including yield strength, ductility, ultimate tensile strength, hardness and toughness/Charpy test. These properties indicate the pipeline and weld metal’s likely susceptibility to hydrogen embrittlement (HE). Without material certificates or stock pipes to verify material properties, the options are extensive testing or operation of the pipeline at a very reduced maximum allowable operating pressure consistent with operating stress equal to or less than 30%. Furthermore, depending on the year of production, standards like API 5L differ in their requirements, producing variability in material design specifications throughout the generations.

Additionally, chemical composition data is essential for evaluating hydrogen compatibility. Certain elements, such as carbon and phosphorus, are correlated with embrittlement. If chemical composition records are unavailable, comprehensive laboratory testing, including Optical Emission Spectroscopy (OES) and combustion analysis, may be required to accurately determine the pipeline's suitability. This process can be costly, especially if many samples are required from different sections of the pipeline. Typical sample sizes range from small cut-outs (10-50 mm) to larger sections if mechanical testing is also required. [10]

Another key consideration is historical material performance and previous modifications. Pipelines with undocumented repairs and replacement sections may contain varying steel grades and weld metal with differing hydrogen compatibility. To assess this variability, mechanical testing such as tensile, impact, and fracture toughness tests can be performed on varying samples. Soaking tests in high-pressure hydrogen environments ranging from hundreds to thousands of hours may be necessary to evaluate long-term embrittlement effects. Access to specialised testing houses is required to accommodate high-pressure hydrogen testing. The cost of testing will vary based on the number of specimens, required exposure times, and analytical techniques used. In general, pipelines with higher strength steels (X70 and above) and welds with elevated hardness levels are more susceptible to embrittlement, whereas lower strength grades with controlled chemistry tend to show better resistance. As described, destructive and non-destructive testing can be costly and time-consuming, reinforcing the importance of material data availability as a key screening criterion for hydrogen feasibility assessments.

3.4 CAPACITY

The capacity of a pipeline is a critical factor in assessing its suitability for hydrogen feasibility. Compared to methane, the primary component of natural gas, hydrogen has one-third of the energy density by volume [11], meaning that flow rates must be three times higher with corresponding higher pressures to deliver an equivalent energy output. This challenges pipelines that are already at capacity, or with velocity limitations and is compounded by the above material compatibility, which can lead to lower operating pressures.

If a pipeline has a low MAOP or would require excessive modifications to maintain adequate hydrogen flow, this will count against it with respect to suitability for repurposing.

3.5 WELDING RECORDS

Welding records are a crucial factor in determining the suitability of a pipeline for hydrogen repurposing, as welds can represent areas of increased susceptibility to hydrogen-related degradation. Pipelines, particularly those constructed before the widespread adoption of stringent welding standards, often lack comprehensive documentation on weld types, procedures, and quality control measures. The absence of such records introduces uncertainty into the assessment and may necessitate conservative assumptions or costly verification testing. A primary concern is the welding procedure used during construction. Different welding processes result in varying microstructures that may have various levels of susceptibility to HE. Post-weld heat treatment (PWHT) and quality control measures play a significant role in mitigating hydrogen-related risks. PWHT can help reduce residual stresses and improve fracture resistance. Still, some pipelines may not have undergone this process, particularly if constructed before modern industry requirements were established. Pipelines with low-toughness welds or high residual stresses are generally at greater risk of hydrogen-induced failure.

Without welding records, it is difficult to determine whether the existing welds meet modern hydrogen compatibility standards.

Pipelines that have undergone multiple weld repairs, undocumented tie-ins, or in-service welding may contain welds of varying quality and unknown metallurgical properties. Such inconsistencies can lead to localised weaknesses that increase the likelihood of crack initiation and propagation. In incomplete records, non-destructive testing (NDT), such as ultrasonic (UT) inspection, may be necessary to detect cracks and analyse their integrity.

If welding records are unavailable or indicate the presence of high-risk welds, the pipeline may require extensive testing or impractical repair before it can be considered for hydrogen repurposing. In a high-level screening assessment, the absence of adequate welding documentation would contribute negatively towards the repurposing decision, requiring further investigation or disqualifying the pipeline from repurposing altogether.

3.6 DEPTH OF BURIAL

Current compliance to ASME B31.12 [10] for hydrogen pipelines states that the minimum depth of cover for buried lines is 0.914 m. Shallow cover areas pose significant risks, particularly in rural and farmland zones where external mechanical interference from excavators and farming machinery could strike the pipeline. Hydrogen causes a reduction in ductility in the steel, making it more susceptible to dents caused by impact, and therefor increasing the likelihood of rupture. To mitigate these risks, concrete slabs and markers can be installed above the pipeline in low-lying areas. In some cases, the surrounding area may be excavated, and the pipeline physically lowered to increase its depth, but this is only practical over relatively short lengths.

Land elevation can change over time from farming, building excavation, and landslides, affecting the depth of burial. Newer pipelines tend to be buried deeper to avoid encroachment on older systems and to comply with changing standards. Due to these changes in terrain and outdated technology previously leading to inconclusive or false results, older pipelines may may require baseline reassessments to ensure accurate data. A Quantitative Risk Assessment (QRA) can justify mitigation efforts or provide a rationale for understanding the risk and recalibrating conclusions accordingly. QRA is particularly valuable for analysing risk areas in relation to population density and proximity to buildings, guiding decisions on whether to tolerate or mitigate risks.

Cost and feasibility are key considerations. Mitigating burial depth risks or installing protective barriers can be expensive, especially over long pipelines, due to excavation costs, material expenses, system downtime, accessibility challenges in farmland or crossings, and long lead times. In some cases, operators may choose to accept the risk of shallow cover if they determine a low likelihood of interference from a QRA. Assumptions can be made based on land use, like recognising farmland as a higher-risk area due to reduced control over landowner activities. It is recommended to conduct sample surveys in problematic areas, informing a QRA to determine the most practical and accountable course of action before implementing extensive mitigation measures.

3.7 ENCROACHMENTS ON RIGHT OF WAY

Encroachment and building proximity must be evaluated when transitioning natural gas pipelines to hydrogen service. Increased population density and building development near pipelines elevate safety risks and maintenance challenges. When repurposing natural gas pipelines for hydrogen, safe distances and blast impact considerations change due to hydrogen's unique properties: higher diffusivity, lower ignition energy, and greater explosiveness in air compared to natural gas. The PRCI Consensus Engineering requirements [12] state that a pipeline with a hydrogen blend < 10% can apply the existing potential impact area (Equation 3-1) in a risk assessment natural gas from ASME B31.8S. [13] For blends exceeding 10%, ASME B31.12 [10] does not define an explicit impact radius but instead focuses on larger safe distances compared with natural gas, based on risk analysis using hydrogen dispersion models.

$$r = 0.69 \cdot (p \cdot D)^{0.5}$$ **Equation 3-1**

Implementing proactive mitigation measures, such as risk assessments, protective barriers, and enhanced monitoring, is essential to ensure safe and reliable hydrogen transportation, with additional significance on the importance of QRA. Many old transmission pipelines run close to settlements; a QRA can help determine if encroachment near a hydrogen pipeline requires mitigation strategies, its status left as is, or if the proximity is so severe that the pipeline will require a rerouting for a less popular area. This is an expensive process demanding new material costs, excavation, and decommissioning of the old route – in situ, purging, grouting, or complete removal.

The likelihood and consequences of potential failures are evaluated through factors such as pipeline condition, population density, proximity to buildings, and risk of third-party interference. If the assessment finds that the probability of failure is low and potential impacts are within acceptable risk thresholds, operators may choose to tolerate the encroachment at risk of substantial financial penalties and lawsuits.

3.8 VALVE SUITABILITY

Block valves are required to sectionalise the pipelines into smaller segments, which can then be isolated in the case of a leak/rupture to minimise the detrimental impact on the environment and the population, as well as facilitate the safe and prompt repair or maintenance of the pipeline. When determining valve spacing, the first consideration should be accessibility to the valves. Other factors involve the conservation of gas, time to blow down the isolated section, continuity of gas service, necessary operating flexibility, expected future development within the valve spacing section, and significant natural conditions that may adversely affect the operation and security of the line.

For newly commissioned hydrogen pipelines, ASME B31.12 [10] stipulates 32 km spacing in Class I, 24 km in Class II, 16 km in Class III, and 8 km in Class IV. These classes determine the design factor of the pipe based on the population density near the pipeline. The correlation between valve spacing and safety is highlighted through the requirement for decreased valve distance in Class IV zones, where older pipelines may be running through high-density urban areas. Spacing distances can be adjusted to permit an installation in a more accessible location. Also, existing valves may not be hydrogen compatible or cannot be demonstrated to be hydrogen compatible, may require replacement.

3.9 ENVIRONMENT IMPACT

The alternative to repurposing is replacement. Pipelines in environmentally sensitive areas with large numbers of crossings or near settlements/housing are expensive and time consuming when permitting and negotiating with landowners. Environmental impact assessments are crucial to address potential effects on ecosystems and groundwater. Environmental protection agencies and local regulatory bodies set guidelines for emissions, safety protocols, and infrastructure modifications. Often repurposing or rehabilitation costs are close to replacement, however operator choose to repurpose or replace due to environmental impact. Comprehensive issues related to replacement are a positive contribution to a repurposing decision.

3.10 COST-BASED WEIGHTING METHODOLOGY

Based on the aforementioned parameters, an assumed cost and cost-based weighting based upon engineering judgment and research conducted by MARCONA, [14] implementing a maximum total cost of adapting a pipeline commissioned before 1984 of €274,000/km for 100% hydrogen service, has been proposed in Table 3.10 1 with the ranking system: 1 being most costly and 10 being the least expensive.

Table 3.10 1: Assumed cost and subsequent weighting per parameter.[1]

Parameter	Assumed Cost (€/km)	Cost Impact Weight (1–10)	Justification
Coating Condition	15,000	8	New coatings: Costs cover removal, surface prep, and reapplication.
Pipeline Condition	50,000	4	Based on integrity assessments for defects, ILI runs and potential repairs
Material Data Availability	12,000	9	Systems may lack records, requiring extensive material sampling and lab testing.
Capacity	55,000	4	Higher pressures may necessitate pipe reinforcement or testing. New compressors are a necessity.
Welding Records	18,000	8	Missing records mean comprehensive assessment of weld metal
Encroachments	24,000	6	Risk assessments, potential rerouting and slabbing.
Depth of Burial	20,000	7	Additional cover or protective measures to prevent damage.
Valve Suitability	70,000	1	Valve upgrades or complete replacement.
Environment	10,000	10	Additional monitoring, advanced leak detection, and regulatory approvals.

4 CASE STUDIES

To demonstrate the application of the proposed screening assessment, two case studies, conducted by Penspen, are presented: Case A, an older pipeline with limited material records and legacy design considerations, and Case B, a newer pipeline built to modern standards. These case studies illustrate how this methodology can be applied to different pipeline generations to provide a high-level screening assessment for suitability of hydrogen repurposing.

4.1 CASE A

Case A examines an older natural gas pipeline being considered for hydrogen repurposing. This pipeline was originally designed and operated under standards and material specifications that may not align with modern hydrogen service requirements. As a result, there are inherent challenges, some of which are considered below. To systematically evaluate the feasibility of repurposing this pipeline, a high-level screening assessment was conducted based on the aforementioned methodology. The distinct lack of missing material and data records related to a derivation of a new MAOP for Case A from ASME

[1] It should be noted, the assumed cost and cost impact ratings outlined in Table 3.10 1 can be adjusted on a case-by-case basis, the values used in this paper are hypothetical.

B31.12 and related material and design factors based on location class. The details of the pipeline under review are summarised in Table 4.1 2.

Table 4.1 2: Case A Pipeline Details.

Pipeline Information		
Construction Year		1967
Pipeline Length [km]		42.03
Line Pipe Data		
Outer Diameter [mm]		720
Wall Thickness [mm]		7.5 / 8 / 9
Material Grade		17GS
Specified Minimum Yield Strength (SMYS) [MPa]		299 / 358 / 348
Specified Minimum Tensile Strength (SMTS) [MPa]		Unknown
Charpy (V-Notch) Toughness [Joules]		76.8 and 40.7 / 101.2 / 44.7
Coating Type	Internal	N/A
	External	Fiberglass reinforced bitumen
Cathodic Protection System		Impressed Current (target protection criterion of 850 mV)
Welding Method		Unknown
Welding Records		Unknown
Depth of Burial		Unknown
Operational Data		
Maximum Allowable Operating Pressure [bar]		55

The details outlined in Table 4.1 2 provide a comprehensive overview of the condition of the Case A, older pipeline. The results of the screening assessment are outlined in Section 4.3.

4.2 Case B

Case B examines a newer natural gas pipeline being considered for hydrogen repurposing. This pipeline was designed and operated under modern standards and material specifications. However, some aspects may not align with modern hydrogen service requirements. As a result, there are inherent challenges, some of which are considered below. To systematically evaluate the feasibility of repurposing this pipeline, a high-level screening assessment was conducted based on the aforementioned methodology. The details of the pipeline under review are summarised in Table 4.2 3.

Table 4.2 3: Case B Pipeline Details.

Pipeline Information		
Construction Year		1997
Pipeline Length [km]		106
Line Pipe Data		
Outer Diameter [mm]		711
Wall Thickness [mm]		8.7 / 11.1 / 12.7 / 15.1
Material Grade		X70
Specified Minimum Yield Strength (SMYS) [MPa]		482
Specified Minimum Tensile Strength (SMTS) [MPa]		565
Charpy (V-Notch) Toughness [Joules]		27
Coating Type	Internal	N/A
	External	Factory Extruded Polyethylene

Cathodic Protection System	Impressed Current (target protection criterion of 850 mV)
Welding Method	Longitudinal Seam Weld
Welding Records	YES
Depth of Burial	YES
Operational Data	
Maximum Allowable Operating Pressure	84

The details outlined in Table 4.2 3 provide a comprehensive overview of the condition of the Case B, older pipeline. The results of the screening assessment are outlined in Section 4.3.

4.3 RESULTS

The following section presents the results of the screening assessment for Cases A and B. The methodology has been structured in a tabular form for ease of application by the user, with parameters listed alongside their assigned ratings and cost-based weighted values (Table 3.10 1), reflecting their relative importance. The 'Engineering Rating (1-10)' value is a qualitative, based upon engineering judgement, 1 being worst case and 10 being ideal where the rating is based on how well the existing parameters aligns with modern H_2 transport requirements. These multiply in each parameter to give the total feasibility score as a percentage.

For Case A (older pipeline) the Engineering Ratings were based on the condition of the asset. In the minimal available data, it was determined that significant remedial repairs and ILI surveys must be undertaken for the pipeline to be fit for hydrogen service. This was based on the number of significant defects recorded along the pipeline coating and surface, alongside insufficient material and pressure data to perform crack analysis and dent assessment.

Case B (newer pipeline) was more promising. The insight onto the current condition of the pipeline was much clearer due to improved data records and recent ILI data, which provided a comprehensive assessment of its integrity. Unlike Case A, where outdated or incomplete records led to uncertainty, Case B benefited from well-documented maintenance history and detailed inspection reports. Additionally, the pipeline in Case B was in far better condition, with fewer signs of corrosion, mechanical damage, or other degradation concerns. This combination of factors significantly enhanced the feasibility of Case B, as it allowed for more accurate assessment, lower expected maintenance costs, and greater confidence in the pipeline's long-term reliability.

Table 4.3 4: Cost Impact Weighted Scores for Case A.

Parameter	Cost Impact Rating (1-10)	Engineering Rating (1-10)	Feasibility Score
Coating Condition	8	3	24
Pipeline Condition	4	3	12
Material Data Availability	9	2	18
Capacity	4	4	16
Welding Records	8	2	16
Encroachments	6	7	42
Depth of Burial	7	6	42
Valve Suitability	1	4	4
Environment	10	9	90
Total Feasibility Score (%)			**29**

Table 4.3 5: Cost Impact Weighted Scores for Case B.

Parameter	Cost Impact Rating (1-10)	Engineering Rating (1-10)	Feasibility Score
Coating Condition	8	8	64
Pipeline Condition	4	8	32
Material Data Availability	9	9	81
Capacity	4	7	28
Welding Records	8	7	56
Encroachments	6	7	42
Depth of Burial	7	10	70
Valve Suitability	1	8	8
Environment	10	9	90
Total Feasibility Score (%)			**52**

As seen in Table 4.3 4 and Table 4.3 5, the total feasibility scores were 29% and 52% associated with Cases A and B respectively. The higher percentage highlighting a pipeline where the repurposing would be deemed more feasible to repurpose through cost and practicability. Figure 4.3 1 highlights the two feasibility scores against a recommended margin of 40% for replacement vs. repurposing. The pipelines below the line could be feasible with remedy or fit for purpose for lower blends of hydrogen.

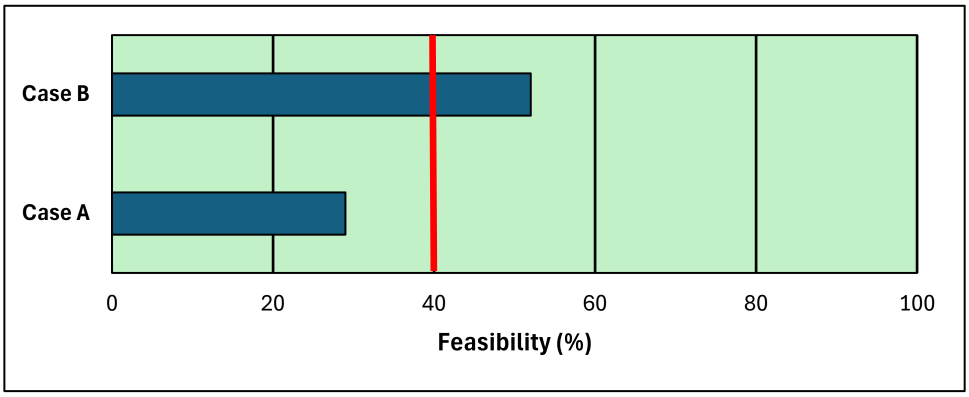

Figure 4.3 1: Bar Chart Highlighting Feasibility of Case A & B in Comparison to

The results of the screening assessments for Cases A and B highlight the contrast between older and newer pipelines in terms of suitability for hydrogen repurposing. Case A, representing an older pipeline, exhibited several challenges, including deteriorated coating, incomplete material and welding records, and uncertainties regarding valve compatibility. These factors increase the likelihood of additional costs such as: material testing, recoating, mitigation strategies, new valves, re-routing, replacement, and inspection before the pipeline could be deemed suitable for hydrogen transport. In contrast, Case B, representing a newer pipeline, benefited from modern coatings, comprehensive documentation, and improved material properties, making it a more viable candidate for repurposing with fewer modifications and easier to run defect assessments. However, even in the newer system, considerations such as environmental exposure and third-party encroachments remain critical factors.

This comparison underscores the potential of a structured high-level screening assessment in determining the feasibility of repurposing natural gas pipelines for hydrogen service. With initiatives such as the EHB [5] aiming to develop approximately 53,000 km of hydrogen pipeline infrastructure by 2040 - 60% of which will come from repurposed natural gas pipelines - operators will face increasing pressure to evaluate the suitability of their assets efficiently. A robust qualitative screening assessment, such as the one applied in this study, allows pipeline operators to triage their networks, prioritising pipelines that demonstrate strong repurposing potential while avoiding unnecessary expenditure on systems unlikely to meet hydrogen service requirements without significant costly remediation.

As hydrogen repurposing projects scale up, particularly in response to decarbonisation goals and EHB objectives, this methodology provides a practical and resource-efficient approach to early-stage decision-making. By filtering pipelines based on key parameters before committing to more detailed engineering assessments, operators can streamline project timelines, allocate resources effectively, and focus investment where it is most needed. This proactive approach will be essential in supporting the rapid deployment of hydrogen infrastructure, ensuring that repurposed pipelines contribute safely and efficiently to the future hydrogen economy.

5 CONCLUSION

The transition to hydrogen as part of global decarbonisation efforts presents a significant opportunity to repurpose existing natural gas pipeline infrastructure. This paper has introduced a structured screening assessment designed to provide a high-level evaluation of a pipeline's suitability for hydrogen service. By considering key factors such as coating condition, material data availability, welding records, encroachment, depth of burial, valve suitability, and environmental considerations, this methodology offers a practical approach for rapidly identifying pipelines that warrant more detailed feasibility studies.

The case studies presented illustrate the application of this screening methodology to both older and newer pipeline systems. While older networks often face challenges related to historical materials, legacy design standards, and incomplete records, newer networks benefit from improved data availability but must still contend with the effects of hydrogen exposure on integrity and operational safety. The flexibility of the proposed screening assessment allows for modifications to account for additional parameters based on industry requirements, ensuring its adaptability to different regulatory environments and operational conditions.

By implementing this structured approach, pipeline operators and stakeholders can streamline decision-making processes, optimise resource allocation, and enhance the safety and efficiency of hydrogen infrastructure development. This methodology contributes to ongoing efforts to repurpose existing pipeline networks while supporting the broader transition to a sustainable hydrogen-based energy system.

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