Future Energy Scenarios: Managing Human Factors Risks in Control Room Operations

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SUMMARY

The progressive transition from natural gas networks to future energy scenarios – to meet the UK's target of achieving net zero by 2050 - will require dynamic changes for operations in Gas Distribution Networks (GDNs). In partnership with three of the UK's four GDNs, Frazer-Nash Consultancy Ltd conducted a study to identify Human Factors (HF) risks, and opportunities for HF best practice, in the design of future gas control room operations. We identified a total of 73 HF risks associated with the implementation of new processes in GDN control rooms to support the transition to net zero; from these, we developed a comprehensive and user-friendly GDN Human Factors Transition Framework, which presents practical guidance on 43 best practice recommendations drawn from HF integration, management of organisational change, and safety culture, to enable the GDNs to proactively manage future HF risks identified. The GDN HF Transition Framework was developed with future energy scenarios in mind; however, it can be applied more widely across the GDN businesses and other industries as a best practice approach to manage HF risk associated with any large scale operational or organisational change.

KEYWORDS

Future Energy Scenarios, Transition Risks, Human Factors in Future Control Room Design

Introduction

Generic Human Factors Issues in Control Rooms

Across all sectors, control room operations present a range of potential Human Factors (HF) risks to safe and efficient operations. Even in stable and 'normal' operational conditions, control room environments present a distinctive combination of safety, usability and ergonomic challenges that can affect operator performance, safety, and system reliability.

Key human factors challenges in control rooms are well-known; for example, research highlights high cognitive workload as a key risk, particularly during abnormal situations and periods of operational change, with operators reporting workload intensity as a key stressor influencing decision making and situational awareness (Janizadeh, 2025). Fatigue represents an additional, well -documented concern, particularly within control rooms operating 24/7 with rotating or extended shifts, where research notes insufficient fatigue management-management processes, limited education on fatigue, and inconsistent break scheduling as notable systemic weaknesses. Fatigue can impact on both cognitive function in the short term, and physical and mental wellbeing in the longer term.

Alongside these cognitive pressures, limitations with Human Machine Interfaces (HMI), such as inconsistent display formats, cluttered visual screens/layouts, and non-standardised alarm systems are widely identified as contributors to operational inefficiencies and increased risk of error. Recurrent issues such as alarm flooding and inconsistent alarm tones hinder operators' ability to interpret information quickly and prioritise tasks effectively during routine and emergency situations.

When any industry is faced with large-scale operational and/or organisational change, many of these HF issues can be amplified. Transitional periods often increase cognitive demands due to new technologies/interfaces, unfamiliar workflows and insufficient support for operator adaptation. Challenges in communication and team coordination also commonly emerge during operational change, where new procedures and mixed system upgrades disrupt collaboration and Shared Situational Awareness (SSA) (Edmonds, 2015). In addition, decisions related to staffing levels and workload distribution, where decisions directly influence an operator's ability to perform safely and effectively, must be made.

Although standards such as British Standard (BS) ISO 11064 provide widely endorsed guidance for the design and optimisation of control rooms, they primarily focus on well-defined, static end-state control rooms. As a result, they offer limited support for managing HF considerations during large scale, phased operational change, or addressing the complexities of dynamic control rooms with a blend of legacy and new operational concepts. This is particularly relevant when considering the unprecedented level of dynamic operational change that the UK's Gas Distribution Networks (GDNs) will face in the transition to future energy scenarios.

UK Gas Distribution Networks (GDNs)

The UK's GDNs supply natural gas and biomethane to 20 million homes and businesses. Historically, the GB gas networks, both transmission and distribution, were owned and operated by a single company for the whole country, leading to consistent practices, standards and systems across the industry. Since 2005, following network sales, the GDNs are now under separate ownership: Wales & West Utilities (WWU), Northern Gas Networks (NGN), Scotland and Southern Gas Networks (SGN), and Cadent. Each GDN has responsibility for a different geographic area, each with its own operational approach, customer base, and asset profile.

Although they operate independently today, the three networks included in this project (WWU, NGN and SGN) share a common background and common challenges across ageing infrastructure, decarbonisation pressures, and the push to leverage new technologies and data to modernise operations and support the UK's transition to net zero.

In recent years, the focus has shifted towards decarbonising the gas network and reducing greenhouse gas emissions, by introducing green gases such as biomethane and hydrogen into the network. Biomethane is now well established, and hydrogen blending is expected to be the next transitional step towards fully hydrogen networks, requiring the network to operate in a range of states. This represents a significant and unprecedented shift in the current operational model, affecting gas quality and settlement processes, infrastructure requirements, consumer interactions, and both commercial and domestic network configurations. The transition will require multiple operational states over an extended period, with teams needing to manage fast-paced, uncertain and evolving conditions as the network moves to a hydrogen network. Given solutions may vary across time and geography the network is likely to go through the transition at different timescales in different regions.

HF issues relating to control rooms are critical to consider in the context of the GDNs as the UK transitions towards net zero by 2050. While the GDNs have worked hard to date to manage HF risks in control rooms for existing operations, for example following best practice for control room design (e.g. EEMUA Guidance 191 and 201), the shift towards a decarbonised system will introduce a unique challenge in control room operations for the GDNs, necessitating new and evolving operational models and associated changes to GDN control room operations and systems. The degree of dynamic operational change associated with the transition to future energies will introduce new HF risks, not least increasing the demand on operators to maintain high level of situational awareness across constantly evolving operational states.

Future Readiness Work 2021-2024

Prior to 2024, the GDN's change management philosophy included minimising the scale and impact of change where possible, making small incremental changes rather than wholescale changes. From a systems perspective, attention was directed towards HMI development, particularly on the Control Room SCADA systems, which System Operation teams can support in-house. Although a change approach had been established, progress against this was an intentionally '*slow and steady*' trajectory to ensure stability and reduce operational disruption.

In response to impending transition, the GDNs have started to proactively understand the anticipated challenges associated with decarbonisation and plan for these. An impact assessment of five future energy/operating scenarios was conducted in 2024, which highlighted significant limitations in the current 24/7 control room operations, demonstrating that the existing control room and associated systems do not have the required flexibility or agility to maintain the effective situational awareness and management during the anticipated transformation. The pace and scale of change also meant that the current 'slow and steady' approach to change would not be viable, and a new approach would be needed.

Situational Awareness Study 2025

Following on from the impact assessment, the GDNs recognised the need to proactively understand the HF risks associated with future control room operations with the proposed energy transition scenarios, to identify forward-facing opportunities for HF best practice to support the GDNs through the transition to hydrogen. This prompted a specific HF study in 2025, in which Frazer-Nash Consultancy were commissioned to support the GDNs in identifying the anticipated HF risks and associated mitigations related to the future dynamic operating scenarios, with particular emphasis on supporting Situational Awareness (SA) and fatigue in a rapidly changing environment. Jointly commissioned by WWU, NGN and SGN through Network Innovation Allowance (NIA) funding, the project aimed to review contemporary body of HF theory relating to SA and fatigue, consider lessons learned from other industries with comparable challenges, identify gaps in current research and practice, and develop recommendations and guidance to support future system design.

Methodology

This project adopted a SME-led and evidence-based approach over a 10-month period, structured into four sequential work packages (Figure 1).

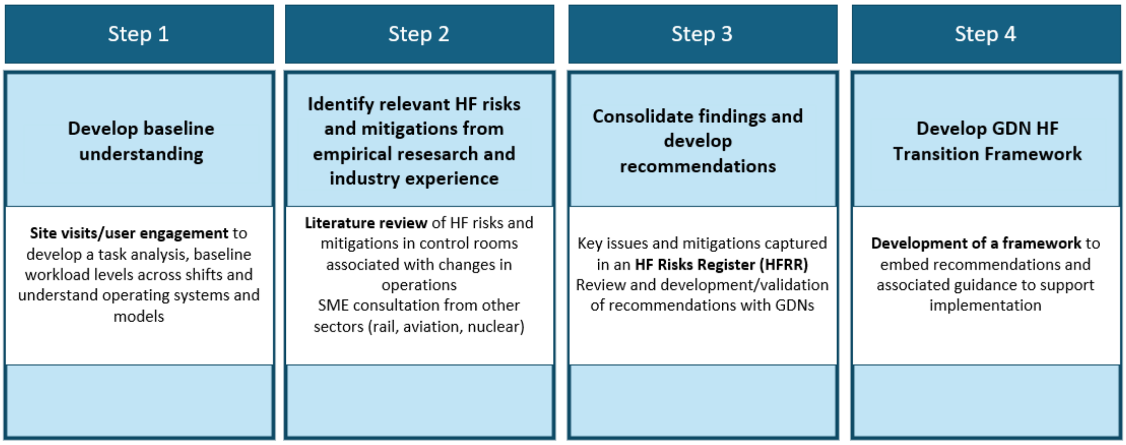

Figure 1- Key Phases and Activities of Study

The work began with developing an understanding of current GDN control room operations, followed by an in-depth, SME-led exploration into the implications of the five future scenarios against 6 sociotechnical areas to provide a structured, human-factors led approach to the consideration of the impact of each scenario (see Table 1 below).

Table 1 - Sociotechnical areas explored for WWU Situational Awareness study

Sociotechnical Model Domain	Characteristics
Infrastructure	The physical aspects of the working environment, which support system operations and interactions.
Technology	The physical hardware e.g. computers, software and HMIs which operators interact with to support system operations and interactions.
People	The individuals responsible for contributing to system operations including their responsibilities, skills, training, relationships, and the broader working environment.
Policies / Procedures	The organisation's standards, policies, regulations, processes, and structures in place to support individuals and operations.
HF Safety Culture	The shared beliefs, values, and norms that influence how people interact with each other and the work environment.
Management of Organisational Change	The process by which changes are managed by the organisation to ensure safety, health, and environmental compliance as well as operational performance.

The methodology adopted was as follows:

Step 1 consisted of a series of activities to develop a baseline understanding of the current operating scenario (Natural gas and biomethane), against which the HF impacts associated with future operating scenarios could be considered. This involved observations in each GDN control room and stakeholder workshops, from which Task Analyses of the Control Room Operators' role in normal operating conditions, across day and night shifts, were developed. SMEs also contributed to a subjective baseline workload assessment, where levels of workload across shifts and associated with different tasks were determined against a visual continuum (low, medium, high).

Step 2 included a literature review which was conducted and complemented by an industry review based on interviews with SMEs (control room HF specialists). The review was conducted to consolidate HF research and industry best practice relating to the areas of interest identified with stakeholders and provided insight into the areas not covered by literature. In addition, a workshop was held with GDN SMEs, including Control Room Operators, to gain their insights into the HF challenges associated with future energy scenarios.

Step 3 aimed to develop a Human Factors Risk Register (HFRR) to capture HF risks identified and relevant forward-facing HF opportunities for best practice. Organised by the impacted sociotechnical area, the HFRR captures the HF risks related to control room operations during the transition phases and their associated best practice HF mitigations.

Step 4 involved the development of the GDN HF transition framework, consolidating the HF best practice opportunities identified in the HFRR into targeted, best practice recommendations, and detailed guidance on how and when these recommended activities should be completed.

Findings

The original focus on this study was to leverage traditional HF activities (SME engagement, control room observations, Task Analysis) to understand the impact of transition and future energy scenarios on situational awareness and fatigue. However, early analysis revealed that the HF challenges facing control room operations in the transition to future energies extend well beyond the situational awareness and fatigue.

Future energy scenarios involve new operational parameters, evolving complexities of Local Distribution Zones (LDZs), greater communication demands, changes monitoring and operational strategies, and time pressures associated with hydrogen introduction and subsequent operation of the network. In total, 73 prospective HF risks were identified in relation to the future energy scenarios and captured in the HFRR, spanning the key sociotechnical areas outlined in Table 1. (A risk can be defined as a potential, uncertain future event that might happen and could negatively affect operational/system performance.)

Key HF risks identified included workload and situational awareness, HMI, policies and procedures (updates and training), emergency preparedness, infrastructure (including ergonomics), staffing (e.g. structure and numbers, shift patterns, recruitment) and culture (e.g. job satisfaction, wellbeing, and morale).

Workload considerations featured as a risk for all future operating scenarios based on anticipated complexity for control room operations during both transition and steady-state operation. While all partners agreed that all future scenarios would create higher levels of complexity and workload than the current operating state, there was no clear consensus on which scenario would create the greatest increase in control room workload.

Generally, the number of HF Risks were broadly consistent across all scenarios, with no notable increase or decrease as hydrogen in the network increases. This indicates that the same core HF issues, risks and best practice activities apply throughout the transition process i.e. the amount of hydrogen in the network does not fundamentally change the HF risks faced by control room operators. However, it may be that some of the HF risks noted would be more complex, or present more demand to control room operators, in certain scenarios, for example those which afford more variability in operational models across the network in any given moment.

The findings revealed that the breadth, scale, and complexity of the forthcoming change to operations could not be addressed through a narrow focus on situational awareness and fatigue alone, or through standard HF integration approaches typically applied to control room upgrades. Instead, the findings of this work highlighted a much wider set of operational and organisation considerations than originally anticipated, with the impact on control room operations extending across all key sociotechnical areas (infrastructure, technology, people, and policies and procedures). Addressing these risks therefore required a forward-thinking, multidisciplinary approach that drew on evidence from HF best practice, organisational change and culture change principles.

Across the sociotechnical areas, 43 best practice activities were defined from the HFRR to support risk mitigation during the transition. These formed the basis for the development of a 'GDN HF Transition Framework', which provides a structured, strategic roadmap of the 43 forward-facing opportunities for HF best practice to support the GDNs through the transition to future energy scenarios.

GDN HF Transition Framework

The HF Transition Framework represents a cohesive and comprehensive approach to managing change, drawing on HFI best practice, culture change, and management of organisational change. The purpose of the framework is to act as guidebook, coordinating and integrating key HF tasks across stakeholders, control room operators, and wider support teams to ensure alignment and operational readiness for significant system changes. The framework outlines the recommended HF activities, describes what "good" looks like and supports the organisation to act as an 'intelligent customer' for procuring HF specialist support, providing structured guidance to inform future phases of control room operational transitions.

The GDN HF Transition Framework is structured into five key phases and maps the best practice HF activities identified from this work across six sociotechnical domains onto an 18-month (recommended) transition timeline. Table 2 provides an illustration of the framework phases and their associated goal. For this paper, the sociotechnical areas 'People', 'HF Safety Culture' and 'Management of Organisational Change' have been selected, with example activities presented for each.

Table 2 - Phases of the GDN HF Transition Framework and their associated goals, with examples of recommended activities for each sociotechnical area

Phases	**Goal**	Sociotechnical area	**Example activity**
1. Align	To coordinate stakeholders, clarify roles and responsibilities, and ensure a shared understanding of objectives before moving into the next phases.	People	Define HF Transition Working Group (WG)
		HF Safety Culture	Establish Senior Leadership Team (SLT) commitment to HF Transitional Framework and initial scope of HF WG
		Management of Organisational Change	Identify / establish Management of Change standard, policy, procedures and processes
2. Define	To thoroughly document and understand the	People	Develop Human Factors Integration Plan

Phases	Goal	Sociotechnical area	Example activity
	existing control room environment, operations, challenges, and strength, and to determine the exact scope of the change.		Conduct Task and Job Analysis for identified roles
		HF Safety Culture	Identify / refine organisation's strategic vision, values and metrics
		Management of Organisational Change	Risk-based screening to identify HF impacts
3. Assess	To determine the potential positive and negative impacts of the change on personnel, processes, and the system once parameters are known.	People	Conduct Workload analysis for identified roles Conduct Training Needs Analysis
		HF Safety Culture	Immerse and diagnose Consolidate and analyse
		Management of Organisational Change	Change impact assessment Risk assessment and consultation
4. Develop	To develop necessary and targeted interventions to support successful implementation and operation of the modified control room.	People	Fatigue Risk Management Plan
		HF Safety Culture	Consult and develop culture change impact plan
		Management of Organisational Change	Transition implementation plan
5.Implement and Review	To develop necessary and targeted interventions to support successful implementation and operation of the modified control room.	HF Verification and Validation of all implemented change across all sociotechnical areas.	

Conclusions

This study represented a successful collaboration between HF specialists and Gas Distribution industry partners to proactively manage the HF risks in control rooms associated with the transition to future energy scenarios. It is an excellent example of a technically rigorous and empirically robust approach leading to the production of an operationally practical and useful output.

The output of the work, the GDN Transition Framework, represents an integrated and comprehensive approach to change, drawing on established best practice across HFI, culture, and management of organisational change. It provides clear and user-friendly guidance on the best practice HF activities relating to change in operations to support a smooth, safe and effective shift from a current operational state to new operational models. Looking beyond the specific transition to future energies, this Transition Framework can be applied as a best practice framework to manage any significant change to operations across any industry, and it is already being implemented by the GDNs to support changes in working arrangements.

This study presented the number of limitations to note: first, the analysis is based on hypothetical future operating scenarios, which remain subject to uncertainty. Further detail will be required as future energy scenarios are defined to enhance understanding of the anticipated challenges and enable the development of more target recommendations.

Second, the project was exploratory in nature, representing the first iteration of a developing approach. The 'Human Factors Transition Framework' is expected to evolve as the approach is applied in practice, drawing on 'Learning From Experience' (LFE) to ensure that the approach continues to align with system and operational requirements.

Third, the scope of the study was limited to control room operations and did not extend to wider organisational functions i.e. support teams or the wider operational workforce.

It is advised that future work should adopt a more holistic operational perspective, including interactions with supporting functions to develop a more comprehensive understanding of the HF considerations across the operational network.

Future application

The HF Transition Framework is designed not only for the GDN control rooms but also has wider applicability, as it is useful for adoption in other sectors where organisations/systems are facing large scale operational change. By providing a structured roadmap of human-centred activities, this framework can support organisational readiness by helping organisations understand the people, processes and system impacts of change and coordinate appropriate interventions. As a result, it is intended that this HF Transition Framework can be used a practical guide to navigate large scale transitions of any origin, ensuring HF, Culture, and Management of Organisational Change remain at the forefront throughout change.

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