Gas Networks Ireland

Future-Proofing Gas Quality Tracking For Ireland's Energy Transition

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1. Executive Summary

Gas quality — including gas composition, calorific value, compressibility and other key properties — will play a central role in Ireland's future energy landscape as the national gas system transitions to incorporate new and increasingly variable gas sources such as Biomethane, LNG, and ultimately Hydrogen.

While the majority of the GNI network currently has strong gas quality measurement coverage, certain areas remain sensitive to dynamic interactions between the two largest existing supply sources (Corrib and the UK Interconnector). These mixing interfaces shift over time based on real-time network demand. As additional renewable and low-carbon gases enter the system, these variations will become more pronounced, making it essential that GNI adapts both its network operations and its tracking and billing methodologies to manage the evolving complexity of the system.

To meet this challenge, GNI has partnered with SmartSim — a German-developed, industry-proven gas quality tracking application — to deliver enhanced modelling and operational transparency across the Irish transmission network.

SmartSim provides:

- Advanced modelling and tracking of varying gas quality flows as they migrate across the network
- Coverage of all current natural gas sources (Corrib and Moffat) and future renewable/lower-carbon sources (Biomethane, LNG, Hydrogen)
- Improved billing accuracy, reflective of the true energy content delivered to customers across all regions and configurations

As part of a major strategic initiative to modernise billing methodologies and support Ireland's decarbonisation pathway, GNI completed a comprehensive Phase 2 validation programme to assess SmartSim's suitability for operational deployment. This 15-month Future-Proofing project included full metrological validation, uncertainty evaluation, and detailed simulation analysis to ensure SmartSim can reliably support billing accuracy, regulatory compliance, and system performance under increasingly diverse gas supply conditions.

The phase 2 project has successfully:

- Provided a rigorous technical and metrological validation of SmartSim's performance on the GNI transmission network
- Demonstrated excellent alignment with Gas Chromatograph (GC) data over a 15-month period across all tested locations
- Completed extensive modelling, uncertainty evaluation (using Monte Carlo methods), and operational scenario simulations
- Confirmed SmartSim's ability to deliver high-accuracy, low-uncertainty gas quality outputs under a wide range of flow and mixing conditions

The outcomes confirm that advanced gas quality tracking is both technically feasible and operationally effective for nationwide deployment.

SmartSim consistently demonstrated precision well within GNI's required tolerances across calorific value, standard density, and CO_2 content, providing the confidence needed for regulatory compliance and high-accuracy customer billing.

With Phase 2 now complete, GNI is positioned to confidently advance to Phase 3, encompassing full system integration, implementation, and final validation in preparation for operational go-live.

The work completed to date has also established a strong foundation for extending similar SmartSim capabilities to the Distribution network, where numerous Biomethane Network Entry Facilities (BNEFs) are already coming online and will expand significantly in the years ahead.

Furthermore, SmartSim provides a future-proofed capability that equips GNI to effectively manage the complexities expected from the introduction of LNG and hydrogen into the Irish network.

The phase 2 works completed ensures that GNI remains resilient, adaptable, and equipped to meet emerging operational, billing, and decarbonisation challenges with confidence.

2. Background & Rationale

The Irish gas network is experiencing increasing variability in gas composition as new supply sources emerge. Traditional billing methodologies—often reliant on fixed gas composition values—are insufficient for a modern network where spatial and temporal variations in gas quality can materially influence energy measurement accuracy.
With future gas supplies expected to include biomethane, hydrogen, and potentially LNG, gas quality across the network will become increasingly variable.

Key challenges include:

- Varying methane content and CV between entry point sources
- Expected biomethane injections, introducing localised quality variations
- Potential future hydrogen and LNG blending
- Limited GC coverage at transmission exit points
- Increasing focus on UAG reductions and decarbonisation targets

SmartSim was identified as a suitable solution through a 2022 feasibility study, which confirmed its capacity to accurately model gas composition and track dynamic gas mixing behavior in the transmission grid.

The SmartSim application provides a more sophisticated, accurate, and future-proof solution compared to existing fixed-component billing methods. This is important to maintain accurate billing, ensure regulatory compliance, and support decarbonization.

3. Introduction

The energy system in Ireland needs to transform to a net-zero or neutral energy system by 2050 at the latest. To achieve this, the gas network, along with all other energy networks, must decarbonise. Gas quality (e.g., composition, calorific value, measurement uncertainty, etc.) will play a crucial role in enabling this as new sources and types of gases become available.

GNI currently has two main sources of gas, from the UK National Grid (Moffat) and the Corrib gas field (Bellanaboy). It is expected that many more entry points will come online in the short to medium term with the introduction of biomethane and the potential introduction of Liquified Natural Gas (LNG) and hydrogen to the network, both locally in Ireland and through the UK entry point.

GNI previously commissioned a study (Future Gas Challenges' report) that examined the challenges posed for GNI in the immediate term, mid-term and long-term. As part of this work, a review of the current billing methodology was carried out to assist with analysing the future effects of gas migration and billing, including the current issue of gas shrinkage. The report recommended that GNI should consider the installation, implementation and integration of a gas quality modelling and tracking system at the GNI Grid Control room.

The SmartSim application provides the following:

- Tracks the natural gases and determines the correct composition mixture for each exit point (calorific value, standard density, carbon dioxide).
- Is used to calculate daily and monthly calorific values (CV) for all customers directly connected to the grid or connected to the downstream distribution grid.
- Is used to determine further gas quality properties needed for computation of the compressibility factor.
- Its implementation and validation have been proven for more than 20 TSOs/DSO in over 30 gas grids within the last 5 years.
- It delivers an individual billing CV for each exit point and thus can ensure a

more accurate billing in today's grid

- In particular, the integration of renewable gases like biomethane and hydrogen is made possible.
- SmartSim ensures correct billing of consumers without the injection of costly fossil Propane injection
- Provides a sustainable solution if several renewable gas sources are connected. Variations would become more dynamic, making it harder to cover the CV measurement with GCs.

The introduction of the SmartSim application with the existing billing methodology will enhance the overall billing application approach and provide more granular detail that will ensure individual customers and regions are billed accurately and compliantly with new emerging gas sources that are being introduced currently and into the future.

The Future Proofing Gas Quality tracking project and phases involved are highlighted below.

- **Phase 1 Pre-study**
  This phase is already completed.
  - Objective to investigate the Phase 1 feasibility in introducing a gas modelling system for the GNI **Transmission** system
  - Feasibility study (1yr+) completed with successful results reported.

- **Phase 2 Pilot**
  This phase involves *piloting the SmartSim application that allows completion of;*
  - *Pre-enablement works (in advance of Phase 3)*
  - *Pre-implementation / development works*
  - *Feasibility / Test / Validation*

- **Phase 3 Implementation**
  - Full System integration, implementation and final validation in preparation for operational go-live.

4. Project Objectives

The Phase 2 programme spans 15 months and included:

- Automation of data interfaces
- Full uncertainty evaluation using updated datasets
- Validation against GC measurements across the network
- Documentation in accordance with ISO 15112
- Installation and configuration within GNI's operational environment
- Trial operation followed by standard operation
- Full system integration with GTMS/IUS platforms

The core goals of the project were to:

1. Validate SmartSim's ability to compute key gas quality parameters (CV, standard density, CO_2 content) across all exit nodes.
2. Ensure alignment with GNI's Code of Operations requirements for energy measurement accuracy.
3. Quantify uncertainty using internationally recognised Monte Carlo methodologies.
4. Assess the system's performance under real-world operating conditions.
5. Provide a basis for future network enhancements and billing methodology improvements.

The expected benefits include:

- For GNI and Network Operations
  - Higher accuracy in energy measurement and billing.
  - Better handling of gas migration and mixing.
  - More efficient system planning and network management.
  - Improved UAG tracking.

- For Customers
  - Enhanced billing, reflecting true gas quality.
  - More consistent service as renewable gases increase.

- For Sustainability
  - Eliminates reliance on propane enrichment.
  - Supports Ireland's renewable gas expansion.
  - Provides necessary infrastructure for hydrogen blending.
  - Enhances environmental compliance and reporting.

5. Methodological Approach

5.1 Metrological Validation Setup

Seven reference GCs were selected as ground-truth measurement points, each providing hourly readings of:

- Superior Calorific Value (CV)
- Standard density
- CO_2 molar fraction

SmartSim simulations were conducted for each hour across the period February 2023–April 2024.
Monthly volume-weighted averages were used for comparison to avoid noise and reflect billing-relevant metrics.

5.2 Uncertainty Analysis Approach

The Monte Carlo method, described in ISO/IEC Guide 98-3, was used to determine expanded uncertainty (k=2) for:

- CV
- Standard density
- CO_2 content

1,600 simulation runs were performed per month, with randomised input variations applied to:

- Injection pressures (±1%)
- Injection and exit volumes (±1%)
- Standard density, CV, CO_2 (±0.1% or ±0.1 mol-%)
- Pipe geometry and roughness
- Gas temperature (±5 K)

The target uncertainty for CV was 0.46%, derived from feasibility study outputs and aligned with acceptable metrological tolerance thresholds.

6. Results

6.1 Metrological Validation

Across the 15-month period:

- Deviations in CV remained below ±0.2%
- Deviations in standard density remained below ±0.3%
- Deviations in CO_2 content remained below ±0.1 mol-%

Mean absolute deviations:

- CV: 0.06%
- Standard density: 0.12%
- CO_2: 0.02 mol-%

This reflects a highly consistent match between SmartSim modelling outputs and the GC reference measurements.

6.2 Uncertainty Evaluation Findings

Median uncertainties:

- CV < 0.1%
- Standard density < 0.1%
- CO_2 < 0.05 mol-%

All exit points with normal flow velocity (>0.02 m/s) remained below the 0.46% CV uncertainty threshold.

Higher uncertainties observed at several low-flow or stagnant nodes were consistent with expected behaviour and have no material billing impact due to minimal volume throughput.

7. Innovation Impact and Benefits

7.1 Operational Benefits

- Accurate, real-time tracking of gas quality across the network
- Improved confidence in billing calculations and energy allocation
- Reduced risk of misallocation during periods of gas migration or flow reversal

7.2 Regulatory and Compliance Benefits

- Supports adherence to GNI Code of Operations accuracy requirements
- Enhances overall metrological robustness of the transmission system

7.3 Strategic and Decarbonisation Benefits

- Enables integration of biomethane, hydrogen, and LNG without compromising measurement accuracy
- Reduces need for additional GC deployments
- Supports Ireland's 2050 net-zero objectives through better gas quality visibility

7.4 UAG and Energy Accounting Improvements

- Improved CV accuracy directly enhances shrinkage calculations and UAG assessment, contributing to more transparent and efficient system operation.

8. Project Learnings

- Accurate gas quality tracking requires both high-fidelity modelling and reliable input data
- Stagnant flow areas remain inherently more uncertain; the impact is isolated and predictable
- Advanced modelling reduces reliance on physical instrumentation expansion

9. Next steps

Following the successful completion of both Phase 1 and Phase 2 of the SmartSim programme, GNI is now positioned to confidently progress to Phase 3, encompassing full system integration, end-to-end implementation, and preparation for operational go-live. The work completed to date has established a robust technical and organisational foundation, enabling GNI to extend similar gas quality tracking and billing capabilities to the Distribution network, which will increasingly accommodate multiple Biomethane Network Entry Facilities (BNEFs) now being introduced and expected to expand significantly in the coming years. Furthermore, the SmartSim application provides a future-proofed platform capable of supporting the integration of LNG and hydrogen into the Irish gas system, ensuring that the network remains resilient, adaptable, and fully prepared for the evolving demands of Ireland's decarbonised energy future.

10. **Conclusion**

The Phase 2 SmartSim validation project confirms that advanced gas quality tracking is both technically feasible and operationally effective for the GNI transmission network. Across a comprehensive 15-month evaluation period, SmartSim consistently demonstrated high accuracy, low uncertainty, and robust performance under a wide range of flow conditions, gas compositions, and network operating scenarios. These outcomes provide strong evidence that SmartSim can reliably support GNI's regulated billing processes, energy accounting requirements, and wider operational needs.

SmartSim Phase 2 represents a significant step forward in modernising GNI's billing and gas quality management capability. The introduction of real-time, network-wide gas quality tracking enhances GNI's ability to manage an increasingly diverse portfolio of gas sources — including biomethane, LNG, and future hydrogen blends — while ensuring customers across Ireland continue to receive accurate, transparent, and equitable billing. The improvements in modelling precision also directly support reductions in Unaccounted for Gas (UAG) and strengthen the integrity of overall system operation.

With the successful completion of Phases 1 and 2, GNI is now positioned to confidently progress to Phase 3, which will involve full system integration, end-to-end implementation, and preparation for operational go-live.

The technical foundations established during the phase 2 programme not only support full deployment on the transmission network but also lay the groundwork for extending a similar SmartSim-enabled configuration to the Distribution network, where the number of Biomethane facilities is projected to expand substantially in the years ahead.

Furthermore, SmartSim provides a future-proofed platform that enables GNI to manage upcoming system complexities associated with LNG imports and hydrogen integration, ensuring the gas network remains resilient, interoperable, and decarbonisation-ready. By investing in advanced gas quality tracking today, GNI is proactively equipping the organisation with the tools required to deliver a secure, low-carbon, and customer-focused energy system for decades to come.