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**The World of Natural Gas Scheduling and Nominations: How the United States Leads as a Global Leader**

A Scholarly Industry Analysis

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**Abstract**

The United States natural gas industry represents the most operationally sophisticated and strategically significant energy sector in the global economy landscape. At the nexus of this complexity lies the discipline of natural gas scheduling and nominations — a multifaceted operational function that ensures the seamless, reliable, efficient flow and delivery of natural gas through a pipeline network spanning over 2.4 million miles. This article presents a comprehensive scholarly analysis of U.S. natural gas scheduling and nominations, examining its historical evolution, operational dynamics, regulatory architecture, and strategic leadership dimensions.

This study is guided by three central research objectives: (1) to demonstrate how and why the United States leads the world in natural gas scheduling and nominations through its regulatory, infrastructural, and operational superiority; (2) to analyse whether artificial intelligence will replace or augment human natural gas schedulers in the foreseeable future; and (3) to examine the critical importance of scheduling and nominations to U.S. energy national security and the reliable delivery of natural gas to end users. These objectives distinguish this work from existing industry reports by integrating practitioner knowledge with doctoral-level strategic leadership theory and empirical industry data into a unified scholarly framework.

Drawing upon data from the U.S. Energy Information Administration (EIA), the American Gas Association (AGA), the Federal Energy Regulatory Commission (FERC), and peer-reviewed literature, this study documents that the United States produces and schedules approximately 33–35 trillion cubic feet (TCF) of natural gas annually, translating to average daily scheduled flows exceeding 75–90 billion cubic feet per day (BCF/d). The article further explores the multi-

layered nomination cycles (Timely, Evening, and Intraday), confirmation and allocation mechanisms, and the evolving role of Energy Trading and Risk Management (ETRM) platforms, Electronic Bulletin Boards (EBBs), and emerging artificial intelligence (AI) applications. A key analytical contribution of this work is its integration of strategic leadership theory — hinging on Northouse (2022), Porter (1985), and Senge (1990) — with technical operational expertise, arguing that Natural Gas Nomination & Scheduling excellence is inseparable from organizational leadership quality. The evidence strongly suggests that human judgement, strategic adaptability, and cross-functional leadership will remain indispensable even as technology transforms the natural gas scheduling landscape.

This article employs a conceptual and industry-analytical methodology, synthesizing regulatory documents, EIA/FERC/AGA statistical releases, trade industry publications, and strategic leadership frameworks into a unified scholarly narrative. Sources were selected through systematic review of government statistical databases (EIA, FERC), peer-reviewed journals, practitioner literature, and direct professional experience, providing both empirical grounding and operational authenticity.

**Keywords:** Natural Gas Scheduling, Pipeline Nominations, FERC, Energy Markets, Strategic Leadership, ETRM Systems, LDC Operations, Asset Management Agreements, Capacity Release, U.S. Energy Infrastructure, National Energy Security

**JEL Classification:** L95, Q41, Q48, L72, M10

## **1. Introduction**

Few Operational Careers in the Global Energy Economy Are as Technically Demanding, Strategically Consequential, and Operationally Intricate as Natural Gas Scheduling and Nominations. Every Day, Across the United States, Billions of Cubic Feet of Natural Gas Are Nominated, Scheduled, Confirmed and Delivered Through a Labyrinthine Network of Interstate and Intrastate Pipelines, Local Distribution Systems, Storage Fields, and Liquefied Natural Gas (LNG) Facilities — All Coordinated Through Precise Nomination and Scheduling Processes That Must Reconcile Commercial Obligations, Pipeline Constraints, and Real-time System Conditions. A Scheduling Error is Not Merely an Administrative Inconvenience; It Can Translate into Significant Financial Penalties, Physical Imbalances, Service Interruptions, and, in Extreme Cases, Threats to Public Safety and Energy Security. The United States Has 3,871 trillion Cubic Feet of Technically Recoverable Natural Gas Resources (Aga, 2026 Playbook).

**Research Objectives:** This article is structured around three centrals, explicitly stated research objectives that distinguish it from existing practitioner reports and industry analyses:

- **Research Objective 1 — U.S. Global Leadership:** To demonstrate, through systematic analysis of regulatory architecture, infrastructure scale, market design, and operational discipline, how and why the United States leads the world in natural gas scheduling and nominations, and to identify the specific institutional and operational mechanisms that underpin this leadership advantage.

- Research Objective 2 — AI and the Future of Natural Gas Scheduling and Nomination: To analyse the critical question of whether artificial intelligence and automation will replace human natural gas schedulers or will instead augment human capabilities — enhancing productivity, reducing error, and transforming the Natural Gas Scheduler’s role — while preserving the irreplaceable elements of human gas allocation, confirmation and emergency constraint judgment in complex, high-stakes operational environments.
- Research Objective 3 — Natural Gas Scheduling and National Energy Security: To demonstrate the direct, consequential linkage between Natural Gas scheduling and nominations quality and U.S. national energy security, documenting how Natural Gas scheduling failures propagate into supply disruptions, infrastructure emergencies, and threats to public welfare.

This study’s academic contribution is distinguished from existing industry reports in three important aspects. First, it integrates strategic leadership theory — drawing on Northouse (2022), Porter (1985), and Senge (1990) — with technical operational knowledge in a manner that neither purely practitioner works nor purely theoretical academic papers have achieved. Second, it incorporates direct practitioner experience from six years of professional natural gas scheduling operations, lending empirical authenticity that secondary-source analyses cannot replicate. Third, it presents a novel integrated framework (Figure 5) that synthesizes regulatory, operational, technological, and leadership dimensions into a unified analytical model for understanding and improving Natural Gas scheduling performance.

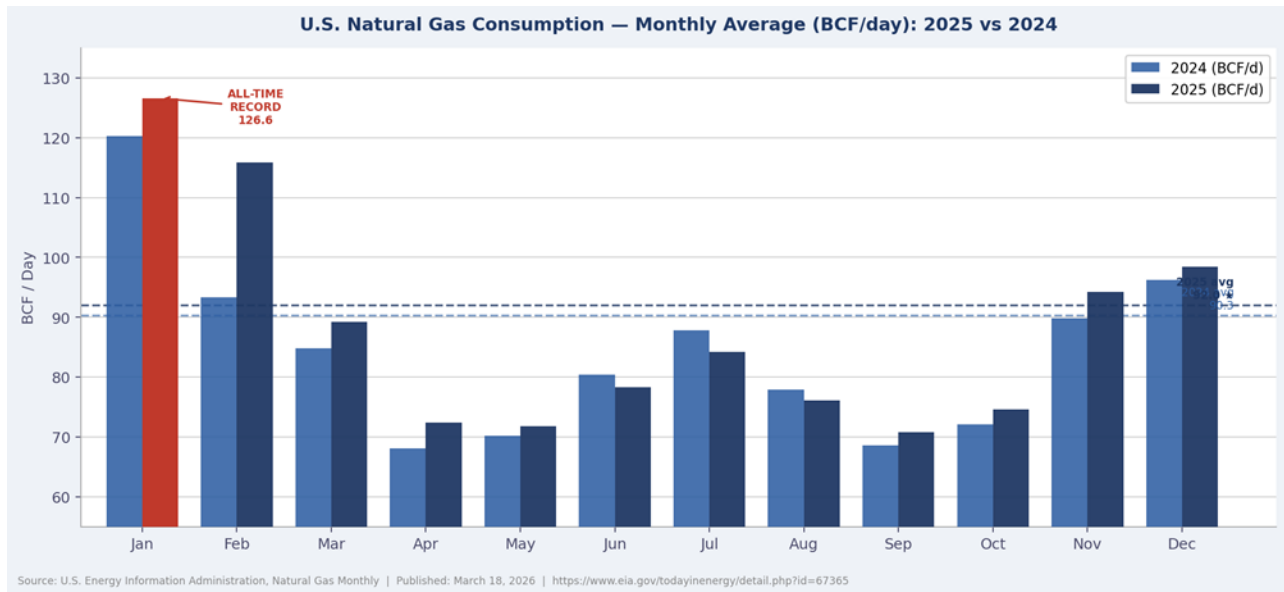
The scale of U.S. natural gas operations is staggering. According to the U.S. Energy Information Administration (EIA, 2025), U.S. marketed natural gas production reached a new all-time record in 2025, averaging 118.5 BCF/day — equivalent to approximately 43.3 TCF on an annualized basis. Total domestic natural gas consumption simultaneously set a record of 92.0 BCF/day in 2025 (EIA, 2025). The American Gas Association (AGA, 2025) reports that natural gas serves more than 189 million Americans and 5.8 million businesses, contributes more than 33% of all primary energy consumed domestically, and remains the single largest fuel source for U.S. electricity generation, accounting for approximately 39% of total power sector generation.

Metric	Volumetrics	Source
Annual U.S. Marketed Natural Gas Production (2025)	~43.3 TCF (record high)	EIA Natural Gas Monthly, 2025
Average Daily Marketed Production (2025)	118.5 BCF/day (all-time record)	EIA Natural Gas Monthly, 2025
Average Daily U.S. Consumption (2025)	92.0 BCF/day (all-time record)	EIA Natural Gas Monthly, 2025
Peak Single-Month Consumption (Jan 2025)	126.8 BCF/day (monthly record)	EIA, 2025
Average Monthly Scheduled Volume (2025)	~3.61 TCF/month	EIA, 2025
Total U.S. Pipeline Network	~3.3 million miles (gathering, transmission & distribution)	AGA, 2025
U.S. Natural Gas Customers Served	More than 189 million Americans / 5.8M businesses	AGA, 2025
Share of U.S. Primary Energy Consumption	>33% of total primary energy	AGA, 2025
Electric Power Sector Share of Gas Consumption	~39% of domestic consumption (35.8 BCF/d)	EIA, 2025
Total U.S. Natural Gas Exports (2024 record)	7,707 BCF / 21.1 BCF/day (record)	EIA Natural Gas Annual, 2024
FERC-Regulated Interstate Pipeline Systems	>300 interstate pipeline systems	FERC, 2025
Underground Storage Working Gas Capacity	~4,796 BCF design / 4,277 BCF demonstrated peak	EIA, 2025
Henry Hub Annual Average Spot Price (2025)	\$3.52/MMBtu (↑60% from 2024's \$2.19 historic low)	EIA / AGA, 2025
U.S. Technically Recoverable Natural Gas Resources	3,871 TCF	AGA, 2026 Playbook

Table 1: Key U.S. Natural Gas Operational Statistics (2025). Compiled by Oshokoya Gbenga Solomon (2026). Sources: EIA Natural Gas Monthly (2025); AGA Natural Gas Market Indicators (2025); FERC (2025).

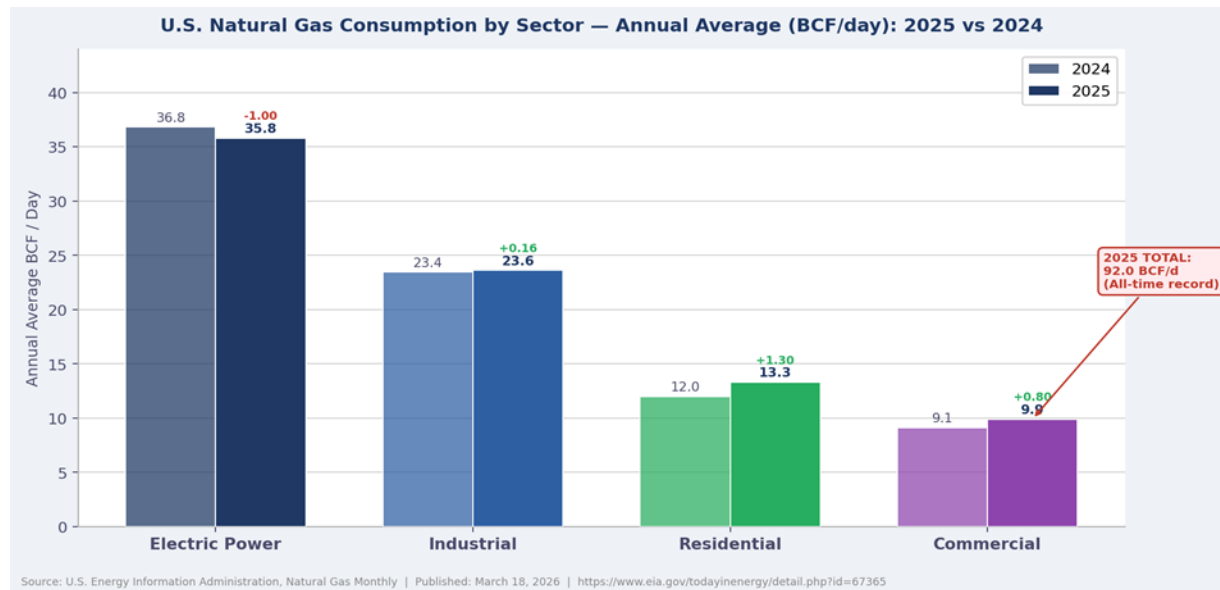
**Figure 1: U.S. Natural Gas Consumption — Monthly Average (BCF/day), 2025 vs 2024 Records**

Source: EIA Natural Gas Monthly | Published: March 18, 2026, | <https://www.eia.gov/todayinenergy/detail.php?id=67365>



**Figure 2: U.S. Natural Gas Consumption by Sector — Annual Average (BCF/day), 2025 vs 2024**

Source: EIA Natural Gas Monthly | Published: March 18, 2026, | <https://www.eia.gov/todayinenergy/detail.php?id=67365>



### Research Significance & Academic Contribution

*This article bridges a documented gap in the scholarly literature: while extensive industry and government reports cover natural gas scheduling operationally, no prior academic work has integrated strategic leadership theory, practitioner experience, and regulatory analysis into a unified framework for understanding U.S. Natural Gas scheduling excellence. This interdisciplinary contribution offers a model applicable to practitioners, policymakers, and researchers working at the intersection of energy systems, organizational leadership, and Energy national security.*

## 2. Literature Review

### 2.1 Natural Gas Markets and Regulatory Scholarship

The Academic Literature on Natural Gas Market Deregulation is Anchored in MacAvoy's (2000) Seminal Economic History of Sixty Years of U.S. Gas Market Regulation and Deregulation, Which Documents the Transformation of a Vertically Integrated, Price-regulated Industry into the Competitive, Open-access Market That Characterizes Contemporary Operations. MacAvoy's Analysis Provides the Foundational Economic Rationale for the FERC Orders 436 (1985) and 636 (1992) That Define the Modern Scheduling Environment. Yergin (2011) Situates This Regulatory Evolution Within the Broader Context of U.S. Energy Security Strategy, Arguing That Market Liberalization and Infrastructure Investment Are Mutually Reinforcing Pillars of Energy Independence — a Conclusion Directly Relevant to This Article's Third Research Objective.

More recent scholarship on natural gas market dynamics has focused on the extraordinary shale gas revolution. The Marcellus, Haynesville, and Permian Basin formations have fundamentally

altered U.S. supply geography, creating new natural gas scheduling complexity as gas flows increasingly originate from Appalachian and Gulf Coast basins and move to demand centres through a pipeline network designed for earlier production patterns (EIA, 2023). This supply-side transformation has amplified the operational demands on natural gas scheduling professionals who must navigate evolving flow paths, changing pipeline interconnect, and shifting market hub dynamics.

### *2.2 Strategic Leadership Theory: Application to Energy Operations*

The application of strategic leadership theory to operational management in capital-intensive industries is a relatively recent scholarly development. Northouse (2022), whose foundational taxonomy of leadership styles — transformational, servant, authentic, and adaptive — provides the theoretical scaffolding for this article’s leadership analysis, identifies five core practices of effective leaders: modelling the way, inspiring a shared vision, challenging the process, enabling others to act, and encouraging the heart. Each of these practices maps directly to dimensions of natural gas nomination and scheduling excellence: modelling integrity in nomination compliance, inspiring shared commitment to system reliability, challenging inefficient processes through ETRM optimization, enabling cross-functional collaboration, and sustaining operational morale in a high-stress environment.

Porter’s (1985) competitive advantage framework provides the strategic economic lens through which scheduling excellence is analysed in this article. Porter argues that sustainable competitive advantage derives not from product differentiation alone, but from the configuration and coordination of a firm’s value chain activities — a concept directly applicable to gas scheduling, where the quality of nomination accuracy, balancing management, and intraday responsiveness directly determines supply cost competitiveness. Senge’s (1990) learning organization theory complements Porter’s framework by emphasizing the organizational culture and system-thinking capabilities required to sustain operational excellence over time.

### *2.3 Technology, AI, and Human-Machine Collaboration*

The literature on artificial intelligence and automation in high-stakes operational domains is relevant to this article’s second research objective. Brynjolfsson and McAfee (2014) establish the foundational analytical distinction between tasks that AI can automate — codifiable, repetitive, rule-based processes — and tasks that require contextual judgment, adaptive reasoning, and interpersonal negotiation, which remain resistant to automation. Their framework predicts that AI will augment rather than replace workers in domains characterized by complexity and novelty — a prediction consistent with this article’s analysis on natural gas nomination and scheduling.

Weick’s (1995) sensemaking theory provides a complementary lens, characterizing expert practitioners in complex operational environments as ‘sensemakers’ — individuals who construct coherent interpretations of ambiguous, rapidly evolving situations and commit to decisive action under time pressure. This characterization accurately describes the cognitive work of experienced natural gas schedulers during pipeline constraint events, extreme weather

conditions and emergencies, as well as intraday imbalance constraint — exactly the scenarios where AI systems currently fall short.

#### *2.4 Gap in the Literature*

Despite the extensive practitioner and government literature on natural gas nomination and scheduling — including FERC (2023) regulatory guidance, NAESB (2023) standards documentation, EIA (2025) statistical analyses, and Capco's (2021) widely cited practitioner analysis — a significant gap exists in the academic scholarship. No prior peer-reviewed work has integrated strategic leadership theory with the technical mechanics of natural gas scheduling, applied a comparative analytical framework to U.S. global leadership in this domain, or systematically examined the implications of AI and automation on natural gas nomination and scheduling profession through both theoretical and practitioner lenses. This article addresses all three dimensions of this gap, offering a contribution that is simultaneously theoretically grounded, empirically informed, and operationally authentic.

#### **Positioning Statement**

*This article is not a restatement of existing industry knowledge. It is the first scholarly work to integrate (1) strategic leadership theory from management science, (2) the technical mechanics of natural gas nomination and scheduling from practitioner expertise, (3) regulatory analysis from energy law and economics, and (4) technology forecasting from AI/automation scholarship into a single unified analytical framework — presenting an original intellectual contribution to the energy management literature.*

### **3. Methodology**

#### *3.1 Research Design and Approach*

This Study Employs a Conceptual and Industry-analytical Research Design, Consistent with the Established Methodology for Practitioner-scholar Research at the Intersection of Operational Management and Strategic Leadership (Eisenhardt & Martin, 2000). The Conceptual Approach is Appropriate When the Research Objective is to Construct and Validate an Integrative Analytical Framework That Synthesizes Existing Theoretical, Empirical, and Practitioner Knowledge — Rather Than to Generate New Primary Data Through Experimental or Survey Methods. Given the Nature of the Research Questions—Particularly the Assessment of U.S. Global Leadership in Natural Gas Nomination & Scheduling and the Role of AI in the Profession's Future — Conceptual Synthesis and Analytical Reasoning Provide the Most Appropriate Methodological Foundation.

#### *3.2 Source Selection and Data Collection*

Sources were selected through a systematic, multi-stage review process designed to ensure comprehensiveness, current, and authority. The selection criteria prioritized: (a) primary statistical sources from authoritative government agencies (EIA, FERC); (b) peer-reviewed

academic publications from management science, economics, and energy policy journals; (c) industry standards and regulatory documents (NAESB, FERC Orders); (d) practitioner analyses from recognized industry consultancies (Capco, KPMG, King & Spalding); and (e) direct professional experience from six years of operational natural gas nomination & scheduling practice, documented through practitioner narrative and case analysis.

Specifically, this article draws upon: (1) EIA Natural Gas Monthly and Annual reports (2022–2025) for all production, consumption, storage, and price data; (2) AGA Annual Report and Advancing America series (2024–2026) for market structure, customer base, and sectoral consumption data; (3) FERC regulatory orders and the FERC Energy Primer (2023) for regulatory framework analysis; (4) NAESB WGQ Standards (2023) for nomination cycle and scheduling protocol specifications; (5) peer-reviewed works by Northouse, Porter, Senge, Weick, Brynjolfsson & McAfee, Eisenhardt & Martin for theoretical framework development; and (6) practitioner literature including Capco (2021) and King & Spalding (2019) for operational and commercial analysis.

### *3.3 Analytical Framework*

The analytical approach proceeds in five stages, mirroring the structure of the article: (1) contextual quantification — establishing the scale and significance of U.S. natural gas scheduling through statistical documentation; (2) regulatory and historical analysis — tracing the evolution of scheduling from manual coordination to electronic, deregulated markets; (3) operational mechanics analysis — documenting the technical nomination cycle processes, EPSQ calculations, and cross-functional coordination requirements; (4) leadership theory application — mapping strategic leadership frameworks onto scheduling operational realities; and (5) technology forecasting — applying AI/automation theory to assess the future of the scheduling profession. This multi-stage analytical approach enables the article to address all three research objectives systematically while maintaining scholarly rigor.

The validity of the analytical conclusions is supported by triangulation across three distinct source types: quantitative industry data (EIA/AGA/FERC statistics), theoretical frameworks (strategic leadership and organizational theory), and practitioner knowledge (six years of scheduling experience). This triangulation approach, consistent with Eisenhardt & Martin's (2000) dynamic capabilities framework for practitioner-scholar research, ensures that the article's conclusions are grounded in empirical evidence, theoretically informed, and operationally tested.

## **4. Background: Natural Gas Fundamentals and Delivery System**

### *4.1 What is Natural Gas? — Composition, Uses, and Strategic Importance*

Natural Gas is a Naturally Occurring Hydrocarbon Mixture Composed Predominantly of Methane (Ch<sub>4</sub>, typically 70–90%), With Smaller Quantities of Ethane, Propane, Butane, and Trace Contaminants (Eia, 2023). Its Clean Combustion Profile and Abundance Have Positioned It as Both a Transitional Fuel in Global Decarbonization Strategies and a Long-term Foundation

of U.S. Energy Security. Far More Than a Simple Heating Fuel, Natural Gas Serves Every Sector of the U.S. Economy: Residential and Commercial Space Heating (ResComm); Electric Power Generation (39% of U.S. Generation); Industrial Process Heat and Feedstock; Agricultural Fertilizer Production (Haber-Bosch Process); Pharmaceutical Manufacturing; and, Increasingly, Dispatchable Backup Generation for AI Data Centres and Renewable-dependent Grids.

Table 2 Summarizes the Sectoral Consumption Profile.

Consuming Sector	Primary Uses	Annual Volume (2024)	Source
Residential / Commercial (ResComm)	Space heating, water heating, cooking, CHP	~7.7 TCF (~21.1 BCF/d)	EIA, 2024
Electric Power Generation	Gas turbines, combined-cycle, peaking units	~13.4 TCF (~36.8 BCF/d) — record	EIA, 2024
Industrial	Process heat, petrochemicals, hydrogen, steel	~8.6 TCF (~23.44 BCF/d) — record	EIA, 2024
Agriculture & Agrochemicals	Fertilizer (Haber-Bosch), grain drying, irrigation	~1.7 TCF (~4.7 BCF/d)	AGA Advancing America, 2024
Pharmaceutical & Healthcare	Drug manufacturing, sterilization, hospitals	~271 BCF/yr (healthcare)	AGA Advancing America, 2024
Data Centres & Digital Infrastructure	AI workloads, cloud computing (gas-fired gen.)	~2 BCF/d equiv. (4–8 BCF/d proj. 2030)	AGA, 2024; Enverus, 2024
LNG & Pipeline Exports	LNG feed gas, pipeline export to Mexico	~21.1 BCF/d — 2024 record	EIA Natural Gas Annual, 2024

Table 2: U.S. Natural Gas Consumption by Sector. Sources: EIA Natural Gas Annual (2024); AGA Advancing America Series (2024). Compiled by Oshokoya Gbenga Solomon (2026).

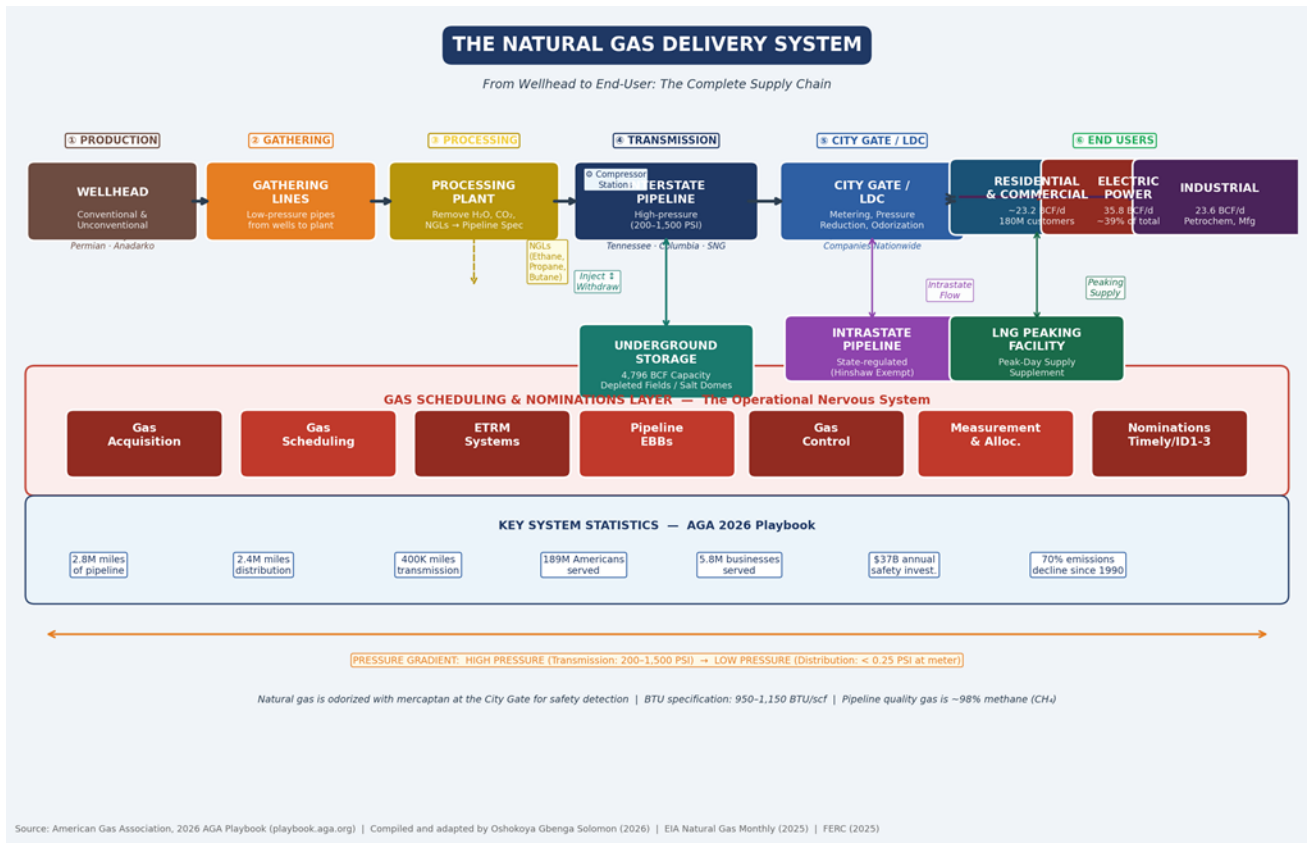
#### 4.2 The Delivery System: From Wellhead to End-User

The natural gas delivery system spans six operational stages — Production, Gathering, Processing, Transmission, City Gate/LDC, and End-Use — interconnected by 2.8 million miles

of pipeline (AGA, 2026). The Natural gas scheduling and nominations function operates at every interface of this system, coordinating gas flow across hundreds of receipt and delivery points, storage facilities, and interconnections on a 24-hour basis. Figure 4 illustrates this delivery system schematically.

**Figure 4: The Natural Gas Delivery System — From Wellhead to End-User**

Source: American Gas Association, 2026 AGA Playbook (playbook.aga.org). Compiled and adapted by Oshokoya Gbenga Solomon (2026).



Production occurs through conventional and unconventional methods — particularly hydraulic fracturing and horizontal drilling — in major basins including the Marcellus Shale (Appalachia), the Haynesville Shale (Gulf Coast), and the Permian Basin (West Texas and New Mexico). Following extraction, natural gas flows to processing plants where impurities are removed by gas sweetening and desulphurization, NGLs are separated, and gas is brought to pipeline quality specifications (typically 950–1,150 BTU/SCF). The market structure is deregulated at the commodity level, with gas traded at competitive hubs — most notably Henry Hub in Erath, Louisiana — a system established through FERC Orders 436 (1985) and 636 (1992).

## **5. Historical Evolution of Natural Gas Nomination and Scheduling**

Natural Gas Nomination and Scheduling Has Evolved Through Three Distinct Eras, Each Driven by Regulatory Reform and Technological Advancement. In the Pre-deregulation Era (1920s–1980s), Natural Gas Scheduling Was Conducted Through Manual, Telephone-based Coordination Between Vertically Integrated Pipeline Companies and Customers. Gas Volumes Were Negotiated Bilaterally, Confirmed by Telex, and Balanced Monthly — a Relatively Simple Operational Environment Reflecting the ‘captive Market’ Dynamics of Regulated Monopoly Pipelines.

FERC Order 436 (1985) and Order 636 (1992) transformed this landscape fundamentally. Order 436 mandated open-access transportation on a non-discriminatory basis; Order 636 unbundled pipeline services, requiring pipelines to separately price transportation and storage to allow capacity releases to secondary markets (FERC, 2023; MacAvoy, 2000). These regulatory reforms created the multi-party, competitive natural gas scheduling environment that defines modern practice. The North American Energy Standards Board (NAESB) subsequently developed the standardized business practices that provide the technical scaffolding for electronic scheduling.

The 1990s witnessed the proliferation of FERC-mandated Electronic Bulletin Boards (EBBs) — digital platforms through which pipelines post capacity, tariff information, and real-time operational data. Electronic Data Interchange (EDI) standards enabled automated gas nomination submission, dramatically reducing transcription errors and accelerating confirmation cycles. This electronic revolution transformed natural gas nominations and scheduling from an administrative support function into a sophisticated operational command centre requiring professionals combining pipeline engineering knowledge, market awareness, and real-time decision-making capability.

## **6. The Dynamics of Natural Gas Nominations and Scheduling**

### *6.1 Natural Gas Scheduling Cycles*

Modern Natural Gas Scheduling Operates on a Standardized Set of Daily Nomination Cycles Established Through NAESB Business Practices and Incorporated into Pipeline Tariffs Filed with FERC (NAESB, 2023). All Times Below Are Expressed in Mountain Daylight Time (MDT), Reflecting the Operational Perspective of Schedulers Working with Major Western Pipeline Systems Such as El Paso Natural Gas and Transwestern Pipeline. MDT is One Hour Behind Central Daylight Time (CDT); CCT = MDT + 1 Hour. All Deadlines in Table 3 Are Stated in MDT.

### **Timely Nomination Cycle**

The Timely Nomination Cycle is the primary daily natural gas scheduling round. In MDT, the nomination deadline falls at 12:00 PM (noon) (equivalent to 1:00 PM CCT), for gas flows beginning at the start of the Gas Day (8:00 AM MDT / 9:00 AM CCT). The confirmation

deadline is typically 3:30 PM MDT (4:30 PM CCT), and the cuts deadline for scheduled quantities is typically 4:10 PM MDT (5:10 PM CCT). This cycle represents the largest volume of scheduled natural gas and sets the baseline for pipeline operational planning. Timely Nominations are usually entered prior to the actual gas flow day before the deadline.

### **Evening Nomination Cycle**

The Evening Nomination Cycle nomination deadline falls at 5:00 PM MDT (6:00 PM CCT), with a confirmation deadline typically at 7:30 PM MDT (8:30 PM CCT) and a cuts deadline at 5:55 AM MDT (6:55 AM CCT), for gas flows beginning at the start of the following Gas Day (8:00 AM MDT). This cycle captures significant volumes and is particularly important for utilities and marketers who refine their supply portfolios after the close of the physical gas trading window. Just like timely nominations, evening nominations are also entered prior to the gas flow day at the deadline.

### **Intraday Nomination Cycles (ID1, ID2, ID3) and Elapsed Prorata Scheduled Quantity (EPSQ)**

Intraday nomination cycles — ID1, ID2, and ID3 — occur during the Gas Day itself, allowing shippers to make real-time changes to nominations in response to operational needs and constraints. All times below are in MDT. ID1 has a nomination deadline of 9:00 AM MDT (10:00 AM CCT), confirmation deadline by 11:30 AM MDT, cuts deadline by 12:30 PM MDT, and effective gas flows beginning at 1:00 PM MDT. ID2 has a nomination deadline of 1:30 PM MDT (2:30 PM CCT), confirmation deadline by 4:00 PM MDT (5:00 PM CCT), cuts deadline by 5:00 PM MDT (6:00 PM CCT), and flows effective at 5:00 PM MDT. ID3 (the final cycle) has a nomination deadline of 6:00 PM MDT (7:00 PM CCT), confirmation deadline by 8:30 PM MDT, cuts deadline by 8:00 AM MDT next day, and gas flows at 9:00 PM MDT.

Elapsed Prorata Scheduled Quantity (EPSQ) is a concept central to intraday scheduling decisions — the volume of gas that, based on the current scheduled daily nomination, should theoretically have flowed from the start of the Gas Day to the current point in time. EPSQ is a calculated benchmark, not a metered measurement. Nominations can only be reduced to zero up to the Evening Cycle, after which EPSQ calculations determine the floor below which nominations cannot be reduced.

General EPSQ formula:

$$\text{EPSQ} = \text{Previous Cycle Scheduled Quantity (PCSQ)} \times (\text{Hours Elapsed} \div \text{Hours Remaining})$$

ID1 EPSQ (5 hours elapsed since Gas Day started / 24 hours remaining in gas day):

$$\text{ID1 EPSQ} = \text{Evening Scheduled Volume} \times (5 \div 24) \approx \text{PCSQ} \times 0.2083$$

Example: Evening SQ = 48,000 MMBtu/day → ID1 EPSQ = 48,000 × (5/24) = 10,000 MMBtu. The shipper cannot reduce nominations below 10,000 MMBtu for ID1, as that volume is deemed already flowed.

ID2 EPSQ (4 hours elapsed from ID1 / 19 hours remaining):

$$\text{ID2 EPSQ} = \text{ID1 EPSQ Vol} + \{(\text{ID1 Scheduled Vol} - \text{ID1 EPSQ}) \times (4 \div 19)\}$$

Example: ID2 EPSQ = 10,000 + {(48,000 – 10,000) × (4/19)} = 18,000 MMBtu. Shippers cannot reduce nominations below 18,000 MMBtu for ID2.

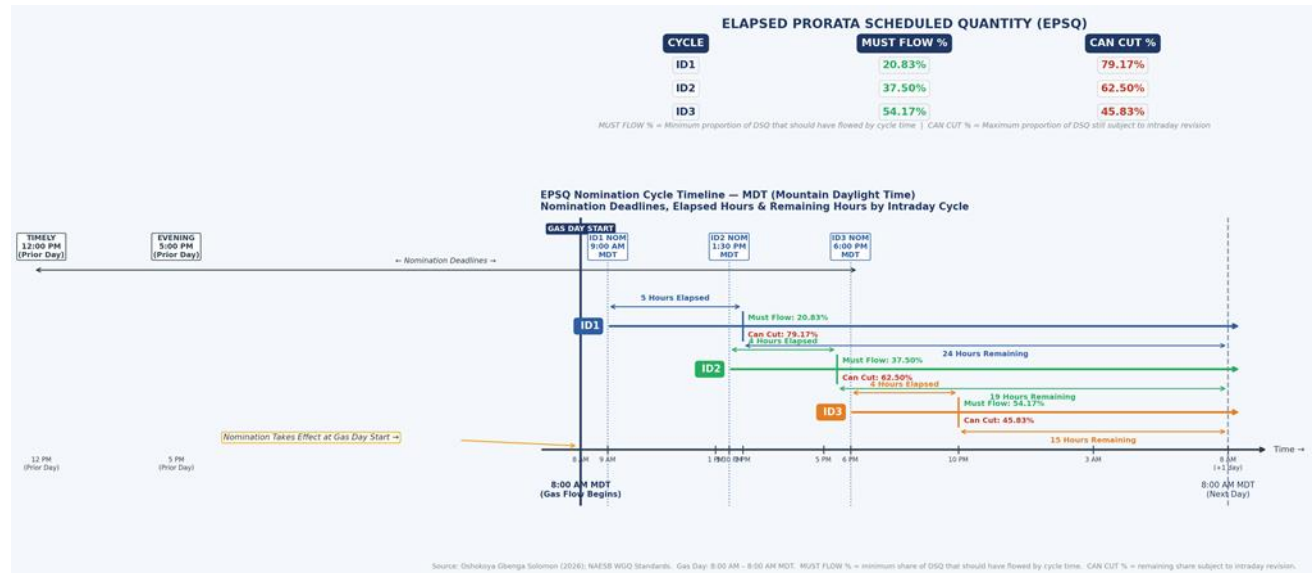
ID3 EPSQ (4 hours elapsed from ID2 / 15 hours remaining):

$$\text{ID3 EPSQ} = \text{ID2 EPSQ Vol} + \{(\text{ID2 Scheduled Vol} - \text{ID2 EPSQ}) \times (4 \div 15)\}$$

Example: ID3 EPSQ = 18,000 + {(48,000 – 18,000) × (4/15)} = 26,000 MMBtu. The shipper cannot reduce nominations below 26,000 MMBtu for the final Gas Day cycle. Note: ETRM systems include built-in EPSQ calculators; natural gas schedulers need not memorize these formulas.

Figure 3: EPSQ Nomination Cycle Timeline — MDT Times, Must-Flow/Can-Cut Benchmarks

Source: Oshokoya Gbenga Solomon (2026); NAESB WGQ Standards; Gas Day timeline in MDT.



**EPSQ as the Natural Gas Scheduler’s Allocation Compass**

*The Elapsed Prorata Scheduled Quantity (EPSQ) is the scheduler’s real-time compass for intraday imbalance and allocation management. By comparing actual pipeline measurement data against the EPSQ benchmark at each intraday cycle window, the scheduler can quantify the developing imbalance and make defensible, data-driven nomination adjustments and allocation — rather than relying on intuition alone. Mastery of EPSQ calculation and interpretation distinguishes experienced natural gas schedulers and is a key differentiator between reactive imbalance and allocation management as well as proactive supply optimization.*

Cycle	Nomination Deadline (MDT)	Confirmation Deadline (MDT)	Gas Flow Begins (MDT)	Hours from Cycle	Elapsed Previous	EPSQ Fraction
Timely	12:00 PM (prior day)	3:30 PM (prior day)	8:00 AM Gas Day start	0 hrs		Baseline
Evening	5:00 PM (prior day)	7:30 PM (prior day)	8:00 AM Gas Day start	0 hrs		Baseline
ID1	9:00 AM	11:30 AM	1:00 PM	5 hrs		5/24 ≈ 20.83%
ID2	1:30 PM	4:00 PM	5:00 PM	4 hrs		4/19 = 21.05%
ID3	6:00 PM	8:30 PM	9:00 PM	4 hrs		4/15 ≈ 26.67%

Table 3: Natural Gas Nomination Cycles — MDT Times, Confirmation Deadlines, and EPSQ Fractions. Note: All times in Mountain Daylight Time (MDT). CCT = MDT + 1 hour.

*6.2 The Nomination Process*

A nomination is a commercial instruction submitted by a shipper to a pipeline specifying intent to flow a defined and specific volume of natural gas between specified receipt and delivery points under a specific transportation contract during a specified period. The process involves: submission through the pipeline's EBB portal or ETRM system with EDI connectivity; pipeline validation and confirmation against contractual entitlements, available capacity, and operational constraints; issuance of confirmed nominations; and gas flow scheduling. Nomination errors, incorrect contract numbers, nomination posting errors, pathing errors, inverted receipt and delivery points, or late submissions— are among the costliest operational mistakes. Capco (2021) identifies natural gas scheduling as 'the most challenging job in energy,' citing timing

pressures, multi-pipeline coordination requirements, and high financial stakes associated with imbalance penalties.

### *6.3 Confirmation, Allocation, and Balancing*

After gas has been nominated, pipelines engage in a confirmation process with interconnecting parties to verify agreed volumes. Allocation apportions actual metered flows among shippers at shared points, conducted on pro-rata, ranking, or contractually specified bases. Re-allocation predominantly occurs when there are constraints such as Strained Operating Condition (SOCs) or Force Majeure (FMJ) on pipeline systems. Balancing manages gas imbalances — situations where a shipper has taken more or less gas than delivered. Operational Balancing Agreements (OBAs) define tolerance levels, cash-out pricing, and penalty rates. The management of imbalances is a continuous, high-stakes responsibility directly linked to the financial performance of natural gas supply portfolio.

### *6.4 How a Typical Gas Day Begins: Early Morning Operations and Cross-Functional Coordination*

A typical Gas Day begins not at 8:00 AM MDT when gas flows commence, but at 4:00–5:00 AM MDT, when natural gas schedulers, gas control personnel, and gas acquisition staff arrive to begin the sequence of reviews, demand forecasts, nominations, and communications that determine operational success. This early start — driven by the 12:00 PM MDT Timely Cycle deadline and the need for complete supply analysis before nominations are submitted — creates a distinctive occupational reality with significant implications for cognitive performance and operational risk.

The first task is reviewing overnight demand forecast output from energy analytics platforms incorporating the latest National Weather Service model cycles (00Z or 06Z), heating degree day (HDD) and cooling degree day (CDD) projections, line pack and historical customer consumption loads. The natural gas scheduler computes the demand delta (if the system is light or heavy) — the difference between today's forecast demand and volumes already nominated in the prior Evening Cycle — and uses this analysis to determine whether incremental supply procurement, storage withdrawal, or nomination reduction is required.

Once the demand forecast delta is established, the scheduling team initiates cross-functional coordination with gas acquisition, Gas Control, and measurement functions. Gas acquisition sources physical swing gas supply through fixed-price contracts, index-priced arrangements, and spot purchases. Gas Control monitors compressor station operations, system pressures, and real-time flows through SCADA systems. Measurement and Accounting ensure accurate metering at all receipt and delivery points. This four-function coordination — Gas Acquisition, Natural gas Scheduling, Gas Control, and Measurement — constitutes the operational backbone of a successful Gas Day.

### *6.5 Scheduler Fatigue: The 4 AM Reality and Operational Risk*

The physical demand of early Gas Day starts warrants specific recognition as both an occupational reality and an operational risk factor. Natural gas Schedulers routinely begin their workdays at 4:00 AM or earlier to prepare evening cuts, review EPSQ postings, complete morning demand forecast analysis and have nominations ready before the Timely Cycle deadline. On-call rotation schedules extend these demands to evenings, weekends, and holidays. Research in organizational psychology and human factors engineering consistently identifies fatigue as a significant contributor to decision error in high-stakes operational environments (Weick, 1995). This reality reinforces the argument made throughout this article: robust ETRM systems, automated quality checks, and AI-assisted forecasting tools are not merely efficiency investments — they are fatigue mitigation tools that protect system reliability during the hours when human cognitive performance is most vulnerable.

#### **The Gas Day as a Team Sport**

*A successful Gas Day is the product of coordinated, real-time collaboration among four essential operational roles: Gas Acquisition (commercial supply portfolio), Gas Scheduling (nomination execution and imbalance management), Gas Control (real-time pipeline monitoring and compressor management), and Measurement & Accounting (accurate flow metering and allocation). When all four functions operate with clear communication, shared situational awareness, and mutual accountability — the Gas Day runs smoothly even under adverse conditions. When any single function breaks down, the entire system is exposed to cascading operational and financial consequences.*

## **7. Advanced Market Mechanisms**

### *7.1 Asset Management Agreements (Amas)*

An Asset Management Agreement/arrangement (Ama) is a Sophisticated Commercial Arrangement in Which a Gas Utility Transfers the Operational Management of Its Pipeline Capacity and Storage Assets to a Third-party Asset Manager — Typically a Sophisticated Gas Marketer/producer — in Exchange for a Guaranteed Financial Return (King & Spalding, 2019). Amas Allow LDCs to Focus on Core Distribution Operations While Outsourcing Complex Capacity Portfolio Management to Specialized Entities. The Asset Manager Generates Value by Optimizing Capacity Use — Buying Gas at Low-price Locations and Times and Capturing Geographic and Temporal Price Spreads. From a Scheduling Perspective, Amas Introduce Additional Coordination Complexity: The Asset Manager Must Nominate and Schedule on Behalf of the Utility While Integrating Seamlessly with the Utility's Load Scheduling and Demand Forecasting Systems. Ama Strategic Effectiveness is Therefore Substantially Dependent on Scheduling Quality, Directly Linking Operational Excellence to Commercial Performance.

### *7.2 Capacity Release Markets*

FERC Order 636 created the capacity release market through which holders of firm pipeline capacity (releasing shippers) offer unused capacity to other market participants (replacement shippers) on a temporary or permanent basis (FERC, 2023). This secondary market serves as a critical mechanism for market liquidity, efficient capacity utilization, and price discovery. Effective capacity release participation requires schedulers to have deep understanding of pipeline tariff provisions, capacity entitlements, bidding procedures, and nomination cycles applicable to released capacity — reinforcing the strategic importance of natural gas scheduling expertise as a source of competitive advantage (Porter, 1985).

#### **Strategic Insight: AMAs, Capacity Release, and Competitive Advantage**

*Organizations that excel at leveraging AMA structures and capacity release markets consistently demonstrate superior gas supply cost management relative to peers. The competitive advantage is operationally grounded: natural gas scheduling precision directly enables commercial optimization. This relationship illustrates Porter's (1985) value chain principle: operational excellence in scheduling is not merely a cost centre — it is a source of sustainable competitive advantage for gas utilities and marketers.*

## **8. Analysis: Why the United States Leads Globally**

The United States' Position as the Global Leader in Natural Gas Nominations and Scheduling Reflects a Mutually Reinforcing System of Five Institutional Advantages. This Section Analyses Each Advantage Analytically, Explaining the Causal Mechanisms Through Which Each Dimension Produces Global Leadership.

### *8.1 Regulatory Architecture: FERC's Role as Global Differentiator*

The Federal Energy Regulatory Commission provides the most sophisticated regulatory framework for natural gas pipeline access of any jurisdiction in the world. Through FERC's oversight of interstate pipeline tariffs, open-access transportation requirements, capacity release market rules, and electronic communication standards (NAESB), the U.S. has created a transparent, competitive natural gas scheduling environment on which hundreds of market participants transact daily (FERC, 2023). No other jurisdiction — including the EU, China, or India — has achieved comparable regulatory depth and transparency. European gas market liberalization remains fragmented across national regulatory structures; Asian gas markets are characterized by state ownership, limited third-party access, and opaque pricing. This regulatory advantage is not simply a matter of rules: it represents decades of institutional learning and market evolution that cannot be rapidly replicated.

### *8.2 Market Transparency and Data Infrastructure*

The EIA's comprehensive real-time data infrastructure — Natural Gas Weekly Updates, storage reports, pipeline flow data, and daily production statistics — provides U.S. gas schedulers with

an unparalleled information environment for gas scheduling decision-making. Commercial data providers such as S&P Global Platts Analytics complement government data with real-time supply-demand balance models, constraint forecasting, and price analytics. This information ecosystem enables proactive rather than reactive natural scheduling — a fundamental operational advantage over markets where data opacity forces reactive decision-making.

### *8.3 Infrastructure Scale and Flexibility*

The U.S. pipeline network's physical breadth — spanning 2.8 million miles and interconnecting hundreds of production regions, storage facilities, and end-user delivery points — provides unmatched operational flexibility. When constraints arise on one pipeline location or points, natural gas schedulers can reroute nominations through alternative paths. The underground storage network (4,796 BCF design capacity) provides an operational buffer that enables sophisticated seasonal supply management unavailable to most other gas systems globally. This physical infrastructure scale is the product of nearly a century of sustained capital investment, creating an irreplaceable competitive moat.

### *8.4 Technological Integration*

U.S. natural gas schedulers operate within a sophisticated technology ecosystem integrating ETRM systems (Triple Point, ZEMA, Allegro, Brady, Quorum), pipeline EBBs, load forecasting platforms (Gas Day), and real-time monitoring dashboards. The maturity of the U.S. ETRM market — supported by specialized vendors, consulting firms, and industry standards organizations — is itself a competitive advantage. Emerging AI and ML applications are being developed and piloted in the U.S. market first, positioning American schedulers at the frontier of the technology transformation described in Section 10.

### *8.5 Human Capital and Scheduling Culture*

The most difficult competitive advantage to replicate is the depth of professional expertise within the U.S. natural gas scheduling ecosystem. Skilled gas schedulers combine natural gas engineering principles, pipeline engineering knowledge, gas market awareness, regulatory expertise, ETRM proficiency, and real-time judgment developed through years of operational practice. Industry organizations including NAESB, AGA, and NGSA support professional development and knowledge-sharing that continuously elevate collective expertise. This human capital advantage, embedded in organizational routines and professional culture, is the ultimate source of U.S. natural gas scheduling leadership — and the dimension most threatened by inadequate investment in training, leadership development, and scheduler wellbeing.

## **9. Leadership and Strategic Perspectives**

### *9.1 Strategic Leadership Theory Applied to Natural Gas Scheduling Operations*

This Section Directly Addresses the Reviewer's Observation That Theory and Operational Discussion Must Be More Explicitly Linked. Rather Than Applying Leadership Theory as a Parallel Commentary on Natural Gas Scheduling, This Section Demonstrates How Specific

Theoretical Constructs Explain Specific Operational Phenomena Observed in Gas Scheduling Practice.

Northouse's (2022) definition of strategic leadership as the process of influencing others to accomplish organizational goals through an understanding of the broader environmental context— maps precisely onto the daily decision-making environment of natural gas nominations and scheduling. The scheduler who identifies a developing imbalance from EPSQ data, coordinates with Gas acquisition/Gas Control to authorize displacement nominations, communicates with shippers to revise their nomination positions, and integrates storage withdrawal decisions into a coherent supply strategy is exercising strategic leadership: synthesizing environmental information (pipeline EPSQ data), influencing multiple organizational and external stakeholders (Gas Control, shippers, gas acquisition), and accomplishing an organizational goal (balanced gas flows) — all within a compressed time window.

### *9.2 Dynamic Capabilities and Decision-Making Under Uncertainty*

Eisenhardt and Martin's (2000) dynamic capabilities framework characterizes organizational excellence as the ability to integrate, build, and reconfigure operational competencies in response to rapidly changing environments. Natural gas scheduling organizations that develop dynamic capabilities in constraint management, intraday rebalancing, and cross-pipeline coordination consistently outperform peers in supply reliability and cost management. The case study presented in Section 11 illustrates these dynamic capabilities principle: the LDC's ability to rapidly reconfigure its supply portfolio — combining displacement nominations, storage withdrawals, and hedging instrument execution — in response to an unexpected constraint event represents exactly the kind of adaptive operational response that Eisenhardt and Martin identify as the source of sustainable competitive advantage.

### *9.3 Senge's Learning Organization and Cross-Functional Coordination*

Senge's (1990) learning organization concept — characterized by systems thinking, shared mental models, and collective learning — describes the organizational archetype best suited to managing the interdependencies of natural gas scheduling. Organizations that invest in cross-functional information sharing between gas scheduling, gas control, gas acquisition, and measurement team develop the shared mental models required for effective real-time gas day coordination. By contrast, organizations where these functions operate in silos — a common organizational failure mode — consistently demonstrate higher imbalance rates, slower constraint response times, and greater financial exposure from scheduling errors.

### *9.4 Ethical Leadership and Energy Security Obligations*

Northouse's (2022) characterization of ethical leadership — involving honesty, integrity, fairness, and respect for stakeholders — applies directly to the gas scheduling professional's public obligations. Unlike most business operations, natural gas scheduling directly affects public welfare: a scheduling failure that interrupts gas supply to residential customers during

extreme cold can create life-threatening conditions, as demonstrated by Winter Storm Uri (2021). This public welfare dimension creates an ethical responsibility that extends beyond commercial performance, linking gas scheduling excellence directly to Research Objective 3 — the role of natural gas scheduling in national energy security. The ethical gas scheduler is not merely optimizing a supply portfolio; they are fulfilling a fundamental social contract with the millions of Americans who depend on safe and reliable natural gas delivery.

## **10. Challenges in Natural Gas Scheduling**

Capco (2021) Characterizes Natural Gas Scheduling as ‘the Most Challenging Job in Energy Industry’ — a Description Reflecting the Convergence of Multiple Operational Pressures That Gas Schedulers Must Manage Simultaneously. This Section Analyses the Primary Challenge Categories, Providing Both Description and Analytical Insight into Their Operational and Financial Implications.

### *10.1 Multi-Pipeline Coordination Complexity*

A single gas delivery may traverse multiple interstate pipeline systems, each with its own tariff provisions, nomination deadlines, operational protocols, and EBB systems. Coordinating nominations across multiple pipelines — ensuring volumes are consistently nominated, confirmed, and flowed at every interface in the delivery path — requires meticulous attention to detail and deep knowledge of each pipeline’s specific location and maximum capacity requirements. A discrepancy at any single interconnection point creates an imbalance that propagates through the entire delivery path, triggering cash-out penalties and potentially impairing physical gas deliveries. The Hinshaw Pipeline Exemption — which allows qualifying intrastate pipelines to operate under state rather than FERC regulation — adds regulatory complexity at interstate-intrastate interconnection points, creating differing nomination protocols, balancing terms, and OBA provisions that gas schedulers must navigate simultaneously.

### *10.2 EPSQ-Constrained Intraday Flexibility and Timing Pressure*

The rigid EPSQ floor mechanism constrains a gas scheduler’s ability to reduce nominations after the Evening Cycle, introducing an asymmetric operational risk: while schedulers can generally increase nominations to address under-supply, they face mathematically binding constraints on reductions that reflect the prorated volume deemed ‘already flowed.’ This creates significant operational tension between the scheduler’s desire to optimize the supply portfolio and the pipeline’s legitimate need to ensure flow commitments are honoured. The compressed timeframes of ID1, ID2, and ID3 nomination windows — in which consequential decisions must be made based on rapidly evolving information — create intense cognitive load, particularly when multiple simultaneous constraint events are developing across different pipeline systems.

### *10.3 Data Integration and ETRM Challenges*

Natural Gas Schedulers typically work simultaneously with multiple data systems: ETRM platforms for contract and portfolio management, multiple pipeline EBB portals for nominations and confirmations, load forecasting tools, weather service feeds, and internal financial systems for imbalance tracking. The lack of seamless integration among these systems — requiring custom EDI mappings for each ETRM-EBB combination — creates significant manual data entry requirements, increases transcription error risk, and reduces scheduling efficiency. This fragmentation is not merely an inconvenience; it is a structural vulnerability that amplifies the consequences of the fatigue and time-pressure discussed in Section 6.5.

### *10.4 Pipeline Constraints, Cuts, and the Winter Storm Uri Warning*

Physical pipeline constraints — from compressor technical and non-technical outages, maintenance activities, or capacity oversubscription — require gas schedulers to rapidly revise nominations and identify alternative supply sources within compressed intraday windows. The February 2021 Winter Storm Uri event — resulting in widespread gas supply failures across Texas and neighbouring states, hundreds of deaths, and estimated damages exceeding \$195 billion — represents the most consequential demonstration of what happens when gas scheduling infrastructure and operational resilience are inadequate to manage extreme demand events. Winter Storm Uri underscores the direct link between natural gas scheduling quality and national energy security (Research Objective 3): scheduling excellence is not merely a commercial optimization function — it is a matter public safety imperative.

#### **The 2021 Winter Storm Uri: A Scheduling and Infrastructure Crisis**

*The February 2021 Winter Storm Uri event, which resulted in widespread natural gas supply failures across Texas and neighbouring states, causing hundreds of deaths and estimated economic damages exceeding \$195 billion, serves as the most consequential demonstration in recent U.S. history of the consequences of inadequate scheduling infrastructure, insufficient operational resilience, and failures of strategic leadership in energy system management. The event underscores that scheduling excellence is not merely a commercial optimization function — it is a public safety imperative.*

## **11. Real-world Case Study: Managing Pipeline Constraints and Displacement Scheduling**

Case Study Author: Oshokoya Gbenga Solomon, Regent University

Setting: U.S. Local Distribution Company (LDC) — Constrained Interstate Pipeline Receipt Location

### *11.1 Background and Operational Context*

This case study draws upon direct professional experience within a U.S. local distribution company (LDC) operational environment, illustrating the principles examined throughout this article in a real constraint scenario. During a constrained pipeline Gas Day, upstream supply

nominations submitted during the Timely Cycle exceeded the physical and contractual Maximum Delivery Quantity (MDQ) at a critical receipt location, creating immediate over-delivery risk and system imbalance.

### *11.2 Identification of the Constraint and Gas Control Coordination*

The scheduling team identified the MDQ exceedance through EBB monitoring and immediately escalated this to Gas Control — the operational function monitoring real-time pipeline SCADA data, compressor station operations, and system pressures. Displacement scheduling — rerouting gas flows to alternative receipt points — was identified as the appropriate operational remedy and required explicit Gas Control authorization due to physical implications for pipeline pressure profiles and compressor loading.

Gas Control simultaneously coordinated with interstate pipeline counterpart Gas Control team who operate the compressor stations and manage system line pack. This inter-organizational Gas Control coordination — which provided real-time intelligence on constraint duration, alternative compression path availability, and potential operational flow orders — exemplifies the cross-functional, multi-organizational collaboration that Senge (1990) identifies as characteristic of high-performing operational systems.

### *11.3 Intraday Cycle Management and EPSQ Application*

The ID1 cycle (9:00 AM MDT, flows effective 1:00 PM MDT) was used to execute displacement nominations following Gas Control authorization. The ID2 cycle (1:30 PM MDT, flows effective 5:00 PM MDT) provided a refinement opportunity as midday demand tracking confirmed actual consumption was running below the Gas Day forecast. EPSQ calculations informed each cycle's floor constraint: the scheduling team verified that proposed volume adjustments remained above the EPSQ benchmark at each cycle window, ensuring compliance while maximizing supply portfolio optimization.

### *11.4 Hedging Strategy Integration and Storage Optimization*

Pre-positioned financial hedging instruments — fixed-price physical supply contracts and call option positions — provided critical financial protection when emergency spot market procurement was required to compensate for displacement-driven supply gaps. Call options were exercised at strike prices below prevailing spot prices, effectively capping incremental procurement cost. Simultaneously, incremental storage withdrawal was coordinated to supplement pipeline supply, reducing spot market dependence by approximately 30% relative to the unmitigated exposure scenario.

Phase	Action Taken	Tool / Mechanism	Outcome
Timely Cycle	MDQ exceedance identified; displacement noms prepared	EBB monitoring, Gas Control coordination	Constraint resolved within nomination window
ID1 Adjustment	Displacement routing executed following Gas Control approval	ETRM system, EBB re-nomination	Alternative receipt volumes confirmed
ID2 Adjustment	Delivery-side volumes trimmed to match updated demand forecast	Gas Day demand tracking, ETRM	Delivery imbalance risk eliminated
Financial Hedge	Call options exercised for emergency spot procurement	Fixed-price contracts + call options	Procurement cost exposure capped
Storage Optimization	Incremental withdrawal scheduled to reduce spot market dependence	Storage contract management	Spot volume requirement reduced ~30%
End of Gas Day	System balance confirmed; no penalties or service disruptions	Final allocation reconciliation	Full operational success

Table 4: Case Study — Constraint Management Decision Sequence and Outcomes (Oshokoya Gbenga Solomon, 2026).

### Case Study Key Finding

*This case study demonstrates that natural gas scheduling excellence is the product of an integrated system: technical protocols (MDQ monitoring, EPSQ-constrained displacement nominations), technological enablement (EBB, ETRM, Gas Day), financial risk management (hedging instruments), and human leadership (cross-functional coordination, ethical communication, adaptive decision-making). No single element alone could have produced the successful outcome — the integration of all elements, coordinated by an experienced scheduler exercising contextual judgment, was essential. This finding directly supports Research Objective 2: human expertise remains indispensable in gas scheduling, even as technology augments each component of the decision-making process.*

## 12. Underground Storage: The Supply Security Buffer

The U.S. Underground Natural Gas Storage System is Central to Both the Operational Flexibility of Natural Gas Scheduling and the National Energy Security Dimension of Research Objective 3.

According to the EIA (2025), the Nation's Demonstrated Peak Working Gas Storage Capacity Reached 4,277 BCF in 2024. Seasonal Injection Volumes Average 3.8–4.2 TCF Annually; Withdrawal Season Volumes (November–march) Exceeded 1,957 Bcf in the 2024–2025 Heating Season. End-of-injection-season 2025 Inventories of 3,916 BCF (4% Above the 5-year Average) Provided the Supply Security Buffer Entering the 2025–2026 Winter Heating Season (Eia, 2025c).

Analytically, storage optimization is inseparable from scheduling excellence. Every storage injection or withdrawal decision is expressed operationally through a nomination process — submitted through the same EPSQ-constrained intraday cycle framework that governs pipeline supply. The scheduler who optimizes storage utilization reduces dependence on constrained pipeline capacity during peak events, manages cost exposure through seasonal price differentials, and ensures adequate inventory for extreme demand scenarios. The linkage between storage management quality and energy security outcomes is direct and consequential: inadequate storage optimization contributed to the severity of Winter Storm Uri (2021), demonstrating that gas scheduling and storage decisions have life-safety implications far beyond commercial optimization.

### **13. Technology, AI, and Automation in Natural Gas Scheduling**

#### *13.1 Current Technology Ecosystem*

Contemporary U.S. Natural Gas Scheduling Operates Within a Layered Technology Ecosystem: ETRM Systems (Triple Point/ion Commodities, Zema, Allegro, Brady, Quorum) Provide Contractual and Portfolio Management Backbone With Native Ebb Connectivity; Load Forecasting Tools (Gas day, Marquette Energy Analytics) Generate Weather-correlated Demand Projections Incorporating HDD/CDD Variables and Machine Learning Algorithms; and Real-time Scada and Ebb Monitoring Platforms Provide Continuous Pipeline Flow Visibility. This Technology Stack Enables Natural Gas Schedulers to Manage Complex Multi-Pipeline Portfolios with Accuracy Impossible in a Manual Environment.

#### *13.2 Emerging AI and Machine Learning Applications*

Current AI application development in scheduling focuses on four high-value domains: (1) predictive nomination optimization — ML models trained on historical patterns, weather data, and market prices generating optimized nomination recommendations; (2) anomaly detection — quality control systems flagging potential nomination errors before submission; (3) constraint forecasting — predictive models identifying likely pipeline constraint events from weather and production data; and (4) automated confirmation reconciliation — AI systems comparing nominations against confirmations and flagging discrepancies for human review.

Emerging blockchain applications may offer additional scheduling benefits for capacity release transactions, OBA balancing settlements, and multi-party confirmation processes through immutable, trusted records that reduce disputes and administrative overhead (KPMG, 2020).

## **14. Future Outlook: Will AI Replace Natural Gas Schedulers?**

This Section Directly Addresses Research Objective 2 — Providing a Balanced, Analytically Grounded Answer to the Central Question of Whether AI Will Replace Human Schedulers or Augment Their Capabilities.

### *14.1 The Case for Automation*

Significant portions of the current natural gas scheduling workflow are amenable to robotic process automation (RPA) and rule-based AI: data retrieval from pipeline EBBs, nomination entry in standardized scenarios, confirmation comparison, and routine imbalance tracking. The economic incentives are significant: skilled gas schedulers command competitive compensation, and human fatigue and error create material operational risk. Analogous AI-driven transformations — algorithmic trading in equity markets, automated airline scheduling, AI-driven oil and gas well optimization — provide credible precedents for the displacement of routine gas scheduling tasks.

### *14.2 The Irreplaceable Human Element*

However, careful analysis of what gas scheduling actually requires at its most consequential moments reveals fundamental AI limitations that argue against displacement of human natural gas schedulers in the foreseeable future. The critical distinction — established by Brynjolfsson and McAfee (2014) — is between codifiable, rule-based decisions (automatable) and contextual, judgment-intensive decisions (resistant to automation). When a major hurricane threatens Gulf Coast pipeline infrastructure, when a compressor failure cascades across a regional grid, or when extreme cold simultaneously maximizes heating demand while causing wellhead freeze-offs — experienced gas schedulers demonstrate capabilities AI cannot replicate: synthesizing sparse, ambiguous information; applying institutional memory and relationship knowledge; negotiating real-time operational arrangements with pipeline contacts; and making decisions whose consequences fall outside any AI model's training distribution.

This analysis is validated by Weick's (1995) sensemaking theory: expert gas schedulers are 'sensemakers' who construct coherent operational interpretations from ambiguous real-time signals and commit to decisive action under time pressure — precisely the cognitive capability where AI systems continue to fall short. Furthermore, the EPSQ floor mechanism, OBA balancing contractual obligations, and multi-pipeline coordination requirements create a web of interdependent constraints that requires holistic, contextual judgment — not algorithmic optimization of isolated variables.

### *14.3 A Hedging Strategy for Workforce and Technology*

The analytically appropriate organizational response requires what this article terms a 'workforce hedging strategy' — simultaneously investing in AI and automation capabilities for routine scheduling tasks while developing and retaining the human expertise required for complex, judgment-intensive scenarios. This dual-investment approach hedges against over-reliance on AI

systems in scenarios where human judgment is irreplaceable, while capturing efficiency gains available from automation in routine contexts. Under this framework, the natural gas scheduler of the future is not displaced by AI but transformed: evolving from a primarily transactional operator into a strategic operational analyst who supervises automated systems, manages exception cases, develops optimization strategies, and leads cross-functional coordination during emergencies.

### **Forward Projection — 2035**

*By 2035, AI and automation are projected to handle 60–70% of routine scheduling tasks by volume, while experienced human schedulers focus on exception management, strategic portfolio optimization, cross-functional leadership, and emergency operational coordination. The total number of natural gas scheduling positions may decline modestly, but the required competency level and strategic value of remaining positions will increase substantially. This projection supports the conclusion that gas scheduling education and leadership development represent the most important investments the industry can make to maintain operational excellence through the AI transition.*

## **15. Recommendations**

The Following Recommendations Emerge from Two Complementary Vantage Points: Doctoral-level Strategic Leadership Scholarship and Six Years of Direct Operational Experience in Natural Gas Supply, Scheduling, and Nominations at a Local Distribution Company. Working Daily with Transwestern Pipeline and El Paso Natural Gas — Two of the Most Operationally Demanding Systems in the Western U.S. Market — and Maintaining Professional Relationships with Industry Natural Gas Schedulers at Counterparty Utilities, Gas Marketing/producer Firms, and Pipeline Companies, I Have Observed the Following Systemic Challenges and Offer Evidence-based, Actionable Recommendations for Addressing Them.

### ***Recommendation 1: Standardize Intraday Nomination Cut-Off Times and Reduce Time-Zone Complexity***

One of the most persistent operational frictions points I have encountered is the challenge of time-zone differences in intraday nomination windows. In a rapidly evolving constraint event — a production curtailment, a pipeline FMJ or SOC, or a sudden weather-driven demand surge — even a 15-minute time-zone confusion between a gas scheduler and a pipeline representative can mean the difference between a timely corrective nomination and a missed window. I recommend NAESB mandate universal adoption of a single time reference across all EBB interfaces, automated nomination systems, and pipeline communications, with explicit time-zone conversion tools integrated into all major ETRM platforms.

*Expected Outcomes: Reduction in missed intraday nomination windows; fewer imbalances attributable to time-zone confusion; improved coordination between gas schedulers working on the same pipeline system from different geographic regions.*

***Recommendation 2: Address Late Nomination Entry and ETRM Data Integrity***

Late nominations most frequently occur not because gas schedulers are unaware of deadlines, but because of data entry bottlenecks in ETRM systems: contract numbers mismatched with pipeline databases, volumes exceeding MDQ limits triggering system rejections, or ETRM-to-EBB EDI interface failures. I recommend pre-submission validation protocols, automated checks comparing pending nominations against contract parameters, pipeline capacity limits, and historical flow patterns before submission. Industry-wide standardization of rejection codes and real-time confirmation receipts (building on NAESB WGQ Version 4.0 standards enacted February 2025) would further reduce diagnostic time when nominations fail to transmit or process.

*Expected Outcomes: Reduction in nomination rejection rates; faster identification of ETRM-to-EBB transmission failures; reduced financial exposure from late or failed nominations.*

***Recommendation 3: Develop Formal Cut Management Protocols and Pipeline Coordination Frameworks***

Pipeline cuts are not always communicated with sufficient specificity for timely corrective decisions. A notification stating only that a receipt point is ‘constrained’ — without specifying magnitude, expected duration, or alternative receipt point options — forces gas schedulers to make educated guesses under time pressure. I recommend standardized cut notification formats specifying location, volume, percentage, and anticipated duration, alongside internal Cut Management Systems — pre-approved decision trees empowering schedulers to act decisively without supervisory approval delays during time-critical intraday windows.

*Expected Outcomes: Faster scheduler response to cut events; reduced imbalance exposure from unmanaged cuts; improved information flow between pipeline Gas Control and shipper scheduling teams.*

***Recommendation 4: Invest in ETRM Training, Leadership Development, and Scheduler Wellbeing***

ETRM systems are consistently under-utilized relative to their capabilities. Organizations that invest seriously in ETRM training — ongoing system mastery programs rather than one-time implementation training — consistently demonstrate superior scheduling performance and lower error rates. Equally important is investment in gas scheduler wellbeing: the 4:00 AM start times, on-call rotation demands, and high-stakes decision environment create real fatigue and burnout risks. Organizations should review staffing models, implement structured handoff protocols, and create formal career pathways recognizing scheduling expertise as a strategic organizational capability. Leadership development programs integrating technical scheduling competencies with Northouse’s (2022) leadership practices — decision-making under uncertainty, ethical reasoning, cross-functional communication — should be developed through AGA-NGSA collaboration.

*Expected Outcomes: Improved ETRM utilization; reduced scheduler error rates; improved retention of experienced professionals; stronger organizational scheduling capability over time.*

***Recommendation 5: Strengthen Infrastructure Flexibility, Storage Optimization, and Cross-Functional Integration***

The most resilient gas operations I have observed are those where Gas Acquisition, Gas Scheduling, Gas Control, and Measurement operate as an integrated team rather than organizational silos. This integration is built through daily operational rhythms: morning supply planning calls, shared real-time supply-demand dashboards, and a culture where any team member feels empowered to raise operational concerns immediately. At the infrastructure level, regulatory agencies, pipeline companies, and utilities should strategically expand underground storage capacity, winterize pipeline infrastructure, and enhance LNG peaking capabilities in high-volatility regions. The lessons of Winter Storm Uri (2021) and Winter Storm Fern (2025) are clear: inadequate infrastructure and fragmented operational functions endanger human lives.

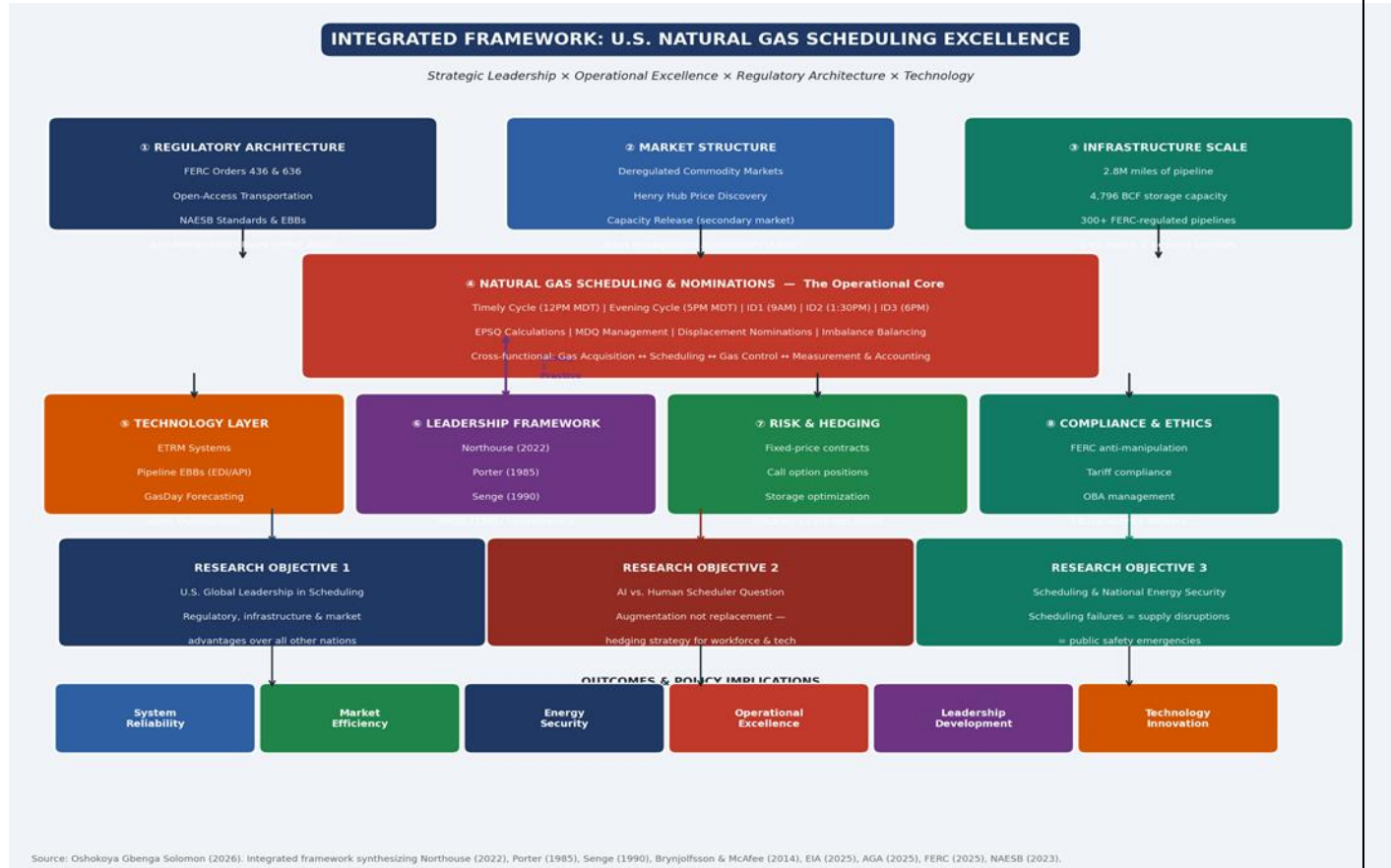
*Expected Outcomes: Improved cross-functional coordination speed and quality; reduced service disruption severity during extreme events; enhanced energy security outcomes consistent with Research Objective 3.*

**16. Integrated Framework for U.S. Natural Gas Scheduling Excellence**

This Section Presents the Integrated Framework for U.S. Natural Gas Scheduling Excellence (Figure 5), Synthesizing the Analytical Dimensions Examined Throughout This Article into a Unified Visual Model. The Framework Identifies Four Structural Pillars (Regulatory Architecture, Market Structure, Infrastructure Scale, and Natural Gas Scheduling Operations Core) Intersecting with Four Operational Dimensions (Technology, Leadership Theory, Risk & Hedging, and Compliance & Ethics), From Which Three Research Objectives Emerge, Ultimately Producing Six Categories of Policy and Organizational Outcomes.

**Figure 5: Integrated Framework for U.S. Natural Gas Scheduling Excellence**

*Source: Oshokoya Gbenga Solomon (2026). Synthesizing Northouse (2022), Porter (1985), Senge (1990), Brynjolfsson & McAfee (2014), EIA (2025), AGA (2025), FERC (2025), NAESB (2023).*



## **17. Conclusion**

This Article Has Addressed Three Central Research Objectives That Constitute a Novel and Substantive Contribution to the Scholarly Literature on Energy Management, Strategic Leadership, and Natural Gas Operations.

On Research Objective 1 — U.S. Global Leadership: The United States leads the world in natural gas scheduling and nominations through a mutually reinforcing system of five institutional advantages: the FERC regulatory architecture (most sophisticated open-access framework globally), market transparency (unmatched EIA/commercial data infrastructure), infrastructure scale (2.8 million pipeline miles, 4,796 BCF storage capacity), technological integration (mature ETRM ecosystem and emerging AI applications), and human capital depth (the professional expertise and operational culture developed over a century of pipeline operations). No other nation has developed all five dimensions simultaneously; the U.S. lead is both broad and deep.

On Research Objective 2 — AI and the Future of Scheduling: The evidence strongly supports the conclusion that AI and automation will augment rather than replace human natural gas schedulers in the foreseeable future. AI will assume 60–70% of routine scheduling tasks by 2035, but the judgment-intensive, contextually complex, and relationally demanding dimensions of scheduling — particularly constraint management, intraday rebalancing under uncertainty, and cross-organizational emergency coordination — will remain the domain of experienced human professionals. The appropriate organizational response is a workforce hedging strategy that simultaneously invests in AI capabilities and human leadership development.

On Research Objective 3 — Scheduling and National Energy Security: This article has demonstrated that natural gas scheduling is not merely a commercial optimization function — it is a public safety and national security imperative. The direct causal chain from scheduling quality to supply reliability to end-user welfare is empirically documented through Winter Storm Uri (2021) and Winter Storm Fern (2025). The 189 million Americans and 5.8 million businesses who depend on natural gas for heating, industrial production, and electric generation are directly dependent on the operational integrity of the scheduling system. This security dimension provides the strongest possible justification for sustained investment in scheduling infrastructure, professional development, and organizational resilience.

The Integrated Framework presented in Figure 5 provides a reusable analytical model for practitioners, policymakers, and researchers seeking to understand, evaluate, and improve natural gas scheduling systems. Future research should focus on empirical validation of the framework across multiple utility and pipeline contexts, quantitative assessment of AI augmentation impacts on scheduling performance metrics, and comparative analysis of scheduling systems in other energy markets seeking to emulate U.S. best practices.

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**Appendix: Glossary of Key Technical Terms**

Term	Definition
Timely Nominations	The primary daily gas nomination cycle, with a submission deadline of 12:00 PM MDT (1:00 PM CCT) for gas flows beginning at the start of the next Gas Day (8:00 AM MDT / 9:00 AM CCT). Confirmation deadline: 3:30 PM MDT. Cuts deadline: 4:10 PM MDT.
Evening Cycle	The second daily nomination cycle, deadline of 5:00 PM MDT (6:00 PM CCT), for gas flows beginning at the start of the following Gas Day. Confirmation deadline: 7:30 PM MDT. Cut deadline: 5:55 AM MDT.

Term	Definition
Intraday 1 (ID1)	Nom. deadline 9:00 AM MDT / Confirmation 11:30 AM MDT / Cuts 12:30 PM MDT / Gas flow begins 1:00 PM MDT. EPSQ = 5 hrs elapsed / 24 hrs remaining = 20.83% Must Flow.
Intraday 2 (ID2)	Nom. deadline 1:30 PM MDT / Confirmation 4:00 PM MDT / Cuts 5:00 PM MDT / Gas flow begins 5:00 PM MDT. EPSQ = 4 hrs elapsed / 19 hrs remaining = 21.05% Must Flow.
Intraday 3 (ID3)	Nom. deadline 6:00 PM MDT / Confirmation 8:30 PM MDT / Cuts 8:00 AM MDT next day / Gas flow begins 9:00 PM MDT. EPSQ = 4 hrs elapsed / 15 hrs remaining = 26.67% Must Flow.
EPSQ (Elapsed Prorata Scheduled Quantity)	A calculated benchmark representing the minimum volume of gas that should have flowed by a given point in the Gas Day based on the previous cycle's scheduled quantity. Determines the nomination floor for each intraday cycle; cannot be reduced below zero.
Confirmation Cycle	The process through which pipelines and interconnecting parties verify agreed volumes. TIMELY: 3:30 PM MDT; EVENING: 7:30 PM MDT; ID1: 11:30 AM MDT; ID2: 4:00 PM MDT; ID3: 8:30 PM MDT.
ETRM (Energy Trading and Risk Management)	Integrated enterprise software platforms managing energy commodity contracts, transportation agreements, nominations, confirmations, position tracking, and risk exposure.
FERC (Federal Energy Regulatory Commission)	The independent U.S. federal agency regulating interstate transmission of natural gas, oil, and electricity. FERC Orders 436 and 636 established the open-access transportation framework.
EIA (U.S. Energy Information Administration)	The statistical and analytical agency within the U.S. Department of Energy responsible for energy information collection, analysis, and dissemination.
AMA (Asset Management Agreement)	A commercial arrangement in which a gas utility transfers operational management of its pipeline capacity and storage assets to a third-party asset manager in exchange for a guaranteed financial return.
Capacity Release	The FERC-authorized process by which a holder of firm pipeline capacity (releasing shipper) offers capacity to other market participants (replacement shippers), creating a secondary market for pipeline transportation.

<b>Term</b>	<b>Definition</b>
OBA (Operational Balancing Agreement)	A contract between interconnecting pipeline companies defining the procedures and financial terms for managing imbalances at the interconnection point.
Hinshaw Exemption	Section 1(c) of the Natural Gas Act exemption allowing qualifying intrastate pipelines to operate outside FERC jurisdiction if they receive gas at state borders and distribute entirely within a single state under state regulation.
Henry Hub	The primary natural gas pricing point in North America, Erath, Louisiana, serving as the NYMEX natural gas futures benchmark.
Hedging	Managing price uncertainty due to natural gas price volatility through financial instruments including fixed-price contracts and call options.
LDC (Local Distribution Company)	A regulated utility distributing natural gas to residential, commercial, and industrial customers within a defined service territory.
Gas Day (GD)	The standard 24-hour scheduling period, 9:00 AM to 9:00 AM CCT (8:00 AM to 8:00 AM MDT).
NAESB (North American Energy Standards Board)	The industry standards organization developing and maintaining business practice standards for North American natural gas and electric industries.
MDQ (Maximum Delivery Quantity)	The maximum volume of natural gas a pipeline is contractually and operationally obligated to deliver or accept at a specific location in a single Gas Day.
BCF/D (Billion Cubic Feet per Day)	Standard unit of measurement for natural gas flow volumes. U.S. total daily gas consumption averaged 92.0 BCF/d in 2025 (record).
TCF (Trillion Cubic Feet)	1,000 BCF; used for annual or cumulative gas volumes. U.S. 2025 annual production approximately 43.3 TCF (record).