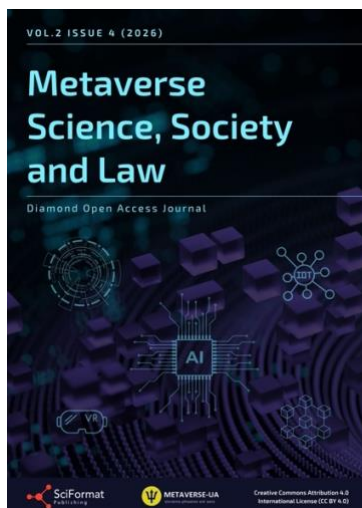




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+15878858911
✉ editorial-office@sciformat.ca

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ALGORITHMIC GOVERNANCE AND CROSS-JURISDICTIONAL REGULATORY INTELLIGENCE: DOCTRINAL, ARCHITECTURAL, AND EMPIRICAL FOUNDATIONS

Kostiantyn Pavroz

Independent Researcher, USA;

National University Odesa Law Academy, Ukraine

ORCID ID: 0009-0003-4025-2712

ABSTRACT

This study develops a jurisprudential, algorithmic, and systems framework for automated regulatory intelligence within the structurally fragmented administrative environment of the United States. Mechanical and HVAC regulation is used as a test domain because a single field operation may simultaneously implicate federal environmental rules, state licensing regimes, county or municipal permitting, locally adopted building codes, technician credentials, and address-specific inspection procedures. Comparative analysis of Illinois, Texas, North Carolina, and Arizona therefore treats the United States not merely as a geographical setting, but as an empirical governance laboratory for examining how artificial intelligence can mediate rules that vary by authority, location, and time.

The analysis addresses three related problems. First, Home Rule, Dillon's Rule, and state preemption distribute local regulatory authority differently across the four states, creating materially different operational pathways (Baker & Rodriguez, 2009; Briffault, 2018; Briffault et al., 2020; Diller, 2017; Mead, 2019; Richardson, 2011; Stahl, 2024). Second, the federal HFC phasedown and EPA Technology Transitions program interact with state and local code-adoption cycles; this interaction may create sequencing gaps or administrative uncertainty, but it should not be characterized as a universal direct conflict or as a federal mandate to use one specific A2L refrigerant (U.S. EPA, 2026a, 2026b). Third, digitally generated compliance records require provenance, temporal reconstruction, qualified certification, and notice procedures if they are later offered under Federal Rules of Evidence 901 or 902(13)/(14); cryptographic hashing alone does not establish admissibility (Krishnamurthy, 2025; U.S. Courts, 2017).

By combining constitutional and administrative analysis, point-in-polygon jurisdictional resolution, temporal knowledge graphs, constrained generative AI, human-in-the-loop governance, and cryptographic provenance, the study proposes a scalable research architecture rather than claiming a completed production platform. The U.S. HVAC case also provides a bridge to Metaverse governance: it demonstrates how physical territory can first become machine-readable, then algorithmically mediated, and comparable to an electronic jurisdiction in which digital space, identity, activity, and time determine the applicable governance regime (Kostenko et al., 2022, 2024, 2025).

KEYWORDS

Automated Regulatory Intelligence; Artificial Intelligence; HVAC Regulation; Temporal Knowledge Graphs; Regulatory Compliance

CITATION

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1. Doctrinal Foundations: Constitutional Municipal Autonomy, Dillon's Rule, and State Preemption Dynamics

Regulation of mechanical, structural, and electrical installations in the United States reflects the allocation of police power between states and their political subdivisions (Baker & Rodriguez, 2009; Briffault et al., 2020; Mead, 2019; Chen, 2020; Zelasko, 2017). The authority to license a trade, adopt or amend a technical code, assess permit fees, or conduct plan review cannot be inferred from the label 'municipality' alone; it depends on the relevant state constitution, enabling statutes, local charter, preemption rules, and the subject matter at issue (Grumm & Murphy, 1974; Mead, 2019; Richardson, 2011).

Dillon's Rule, associated with Judge John F. Dillon's nineteenth-century formulation and later judicial use, operates as a restrictive canon for construing municipal powers: local governments generally exercise powers expressly granted, necessarily or fairly implied, or indispensable to their declared purposes (Grumm & Murphy, 1974; Mead, 2019; Nolon, 2020; Richardson, 2011; Newcomb, 2021; Zavydniak, 2025). Its practical effect varies by state and by subject. Accordingly, the doctrine should be modeled as a jurisdiction-specific interpretive constraint rather than as a universal rule that automatically invalidates every unenumerated local administrative practice.

Home Rule provisions shift this baseline by granting qualifying local governments broader authority over local affairs, often including public health and safety, licensing, taxation, and code administration (Baker & Rodriguez, 2009; Diller, 2017; Nolon, 2020; Chen, 2022b; Chen & Sullivan, 2025; Gutierrez-Alvarez, 2026; Radom et al., 2025). Home Rule nevertheless remains bounded by state constitutional limits, express preemption, and judicial distinctions between local affairs and matters of statewide concern (Briffault et al., 2020; Stahl, 2015, 2024). For computational purposes, Home Rule is therefore not a binary permission flag; it is a bundle of powers whose scope must be linked to the relevant activity and controlling authority.

The model must also represent contemporary state preemption, including statutes that expressly displace local ordinances or establish regulatory ceilings (Briffault, 2018; Fox, 2017; Moe, 2026; Swanson & Barrilleaux, 2018). Rather than assuming that the most protective or most local rule controls, an automated system must record the source, scope, effective period, and conflict relation of each rule, and route unresolved questions to expert review.

1.1 Illinois Constitutional Architecture and Municipal Empirical Reality

Illinois provides an expansive constitutional Home Rule model under Article VII, Section 6 of the 1970 Illinois Constitution. A county with an elected chief executive and a municipality with a population above 25,000 are home-rule units, while other municipalities may elect Home Rule by referendum; the legal status of a locality must be verified from current official records rather than inferred from population alone (Ill. Const. art. VII, § 6; Baker & Rodriguez, 2009; Diller, 2017; Chen, 2022a; Walshe, 2019).

Section 6(a) authorizes a home-rule unit to exercise powers pertaining to its government and affairs, including regulation for public health and safety and licensing. Illinois does not provide a single unified statewide HVAC/mechanical contractor license equivalent to those used in some other states, although trade-specific state rules may still apply. Consequently, contractor registration, permitting, adopted code editions, and inspection procedures can vary substantially by municipality or county and must be verified at the local level.

Article VII, Section 6 also specifies how the General Assembly may limit or deny Home Rule powers. The operational consequence is visible in the Chicago metropolitan area: an address associated with 'Schaumburg' for postal purposes may fall within the incorporated Village of Schaumburg, unincorporated Cook County, or unincorporated DuPage County. These territories may use different portals, registration requirements, fees, code editions, and review pathways. This field reality supplies the central U.S. empirical problem addressed by the proposed architecture.

1.2 Texas Structural Framework: Charter Autonomy and Aggressive Preemption

Texas permits cities with more than 5,000 inhabitants to adopt or amend home-rule charters under Article XI, Section 5 of the Texas Constitution; smaller municipalities generally operate under statutory general-law authority (Tex. Const. art. XI, § 5). The computational task is therefore twofold: determine the city's charter status and then test whether a state statute preempts the particular local requirement.

Cities such as Austin administer localized permitting and code workflows through digital systems, while statewide licensing and preemption statutes constrain the permissible range of local action. A regulatory intelligence engine designed for Texas must not presume that a local portal or ordinance is dispositive; it must evaluate the local rule against the current statewide statutory baseline and preserve the reasoning path for human review (Briffault, 2018; Fox, 2017; Swanson & Barrilleaux, 2018).

1.3 North Carolina Administrative Framework: Modified Dillon's Rule and Code Uniformity

North Carolina is frequently described through a modified Dillon's Rule tradition, but local authority is governed by the text and construction of the applicable statutory grants, including Chapters 143, 153A, and 160A of the General Statutes (Mead, 2019; Nolon, 2020; Richardson, 2011). Chapter 143 is the operative source for the statewide technical baseline: Article 9 of that chapter establishes the State Building Code Council and the North Carolina State Building Code, so it must be encoded alongside the general municipal and county enabling chapters rather than treated as peripheral. The model should therefore encode the relevant enabling provisions rather than rely on a generalized doctrinal label.

North Carolina's State Building Code supplies a comparatively uniform technical baseline, while local agencies administer permits, inspections, scheduling, and enforcement. This reduces some substantive code variance but does not eliminate administrative variation or the need to verify licensing, permit type, adopted procedures, and the specific enforcement authority. The North Carolina case thus tests whether the architecture can distinguish uniform substantive rules from locally variable workflow rules.

1.4 Arizona Statutory Model: Charter Cities and Strict Ceiling Preemption

Arizona combines constitutional charter-city authority under Article XIII, Section 2 with statutory grants and limits governing municipalities and counties. Contractor licensing is administered at the state level through the Arizona Registrar of Contractors, while local governments retain important permitting, zoning, and inspection functions (Ariz. Const. art. XIII, § 2; Ariz. Rev. Stat. tits. 9, 11, 32).

Because Arizona's operative limits are distributed across several statutory titles, the analysis should not attribute all permitting ceilings, processing deadlines, or contractor-bonding rules to a single provision such as A.R.S. § 11-819. A defensible compliance model must identify the exact statute applicable to the government type, permit, and contractor classification, then distinguish state licensing requirements from local administrative procedures.

Table 1 compares the four state governance structures without treating any classification as exhaustive. Its purpose is to show why the same technical task requires different choice-of-authority logic across U.S. jurisdictions and why regulatory intelligence must begin with authority resolution rather than with rule retrieval alone.

Table 1. Cross-Jurisdictional Comparative Constitutional Analysis

State Jurisdiction	Constitutional / Statutory Authority	Local Governance Classification	Mechanical Licensing Level	Preemption Mechanism & Statutory Trigger
Illinois	Ill. Const. art. VII, § 6; 65 ILCS 5	Constitutional Home Rule for qualifying units; statutory authority for others	No unified statewide HVAC and mechanical contractor license; local registration and trade-specific requirements vary	Express constitutional and statutory limits; subject-specific preemption and concurrent authority must be tested
Texas	Tex. Const. art. XI, § 5; Tex. Loc. Gov't Code	Home-rule charter cities (>5,000); general-law municipalities	State HVAC licensing through TDLR, plus locally administered permitting or registration where authorized	State statutes may expressly preempt or constrain local charter action
North Carolina	N.C. Gen. Stat. chs. 143, 153A, 160A	Statutory local authority; comparatively uniform State Building Code	State occupational licensing with local permit and inspection administration	Enabling statutes and statewide code limit local substantive variation; workflows still vary
Arizona	Ariz. Const. art. XIII, § 2; A.R.S. tits. 9, 11, 32	Charter-city authority; statutory municipal and county powers	State contractor licensing through ROC; local permitting, zoning, and inspections	Different statutory limits apply by government type, permit, and contractor classification

Note. This taxonomy is a research model, not a substitute for current legal verification. Each deployment must confirm the locality's present Home Rule or charter status, governing statutes, license type, code adoption, and agency practice from primary official sources.

2. Vertical Statutory Dynamics: Federal Environmental Decarbonization and Municipal Safety Code Friction

Vertical regulatory friction arises when federal environmental policy, federal equipment-use restrictions, state rules, voluntary consensus standards, model codes, and locally adopted code editions evolve on different schedules (Essien et al., 2025; Fox, 2017). The HFC phasedown under the American Innovation and Manufacturing (AIM) Act and EPA's Technology Transitions program illustrates this layered problem, while Clean Air Act Section 608 separately governs technician certification, refrigerant handling, recovery, and anti-venting obligations (40 C.F.R. pts. 82, 84; U.S. EPA, 2026a, 2026b).

The AIM Act authorizes an 85% phasedown of HFC production and consumption from baseline levels by 2036. EPA's Technology Transitions regulations impose sector- and subsector-specific GWP limits and compliance dates. For certain residential and light-commercial air-conditioning products, manufacturing and import restrictions began in 2025, while component-system installation and inventory transition rules include later dates and defined exceptions. The regulations do not legally require a single named refrigerant. R-32 and R-454B are examined here as prominent lower-GWP market responses; both are classified as A2L under ASHRAE Standard 34, indicating lower toxicity and lower flammability than more highly flammable classifications (U.S. EPA, 2026a, 2026b; OSHA, 2024).

Installation permits and mechanical inspections remain largely local functions conducted under state or locally adopted versions of the International Mechanical Code, International Residential Code, and related amendments. Where an authority is using an older code edition or has not yet issued clear A2L guidance, contractors may encounter uncertainty about acceptable equipment, charge limits, detection or mitigation requirements, documentation, and inspection practice. This is better understood as a code-adoption and implementation lag than as proof that local law categorically conflicts with federal law (Mir-Hosseini et al., 2026; Newcomb, 2021; Zhu et al., 2023).

This asynchronous transition creates several operational questions for contractors and for any proposed compliance-support architecture:

- Federal rules limit production, import, sale, distribution, or installation of specified high-GWP products and systems according to subsector-specific dates, while Section 608 imposes separate technician and refrigerant-management duties. The applicable federal requirement must therefore be resolved by equipment category and transaction type rather than reduced to a single 'A2L mandate.'
- State and local authorities may apply different code editions, amendments, permit classifications, and evidentiary requirements. A contractor may therefore need agency confirmation, manufacturer documentation, or engineering review even when the equipment is lawful under the relevant federal technology-transition rule.

A proposed regulatory intelligence system should maintain dated mappings of Authority Having Jurisdiction (AHJ) rules, verify technician credentials, identify the code edition and local amendments, and distinguish a verified permit pathway from an inferred one (Ford et al., 2026; Li & Zhou, 2026). Where the official source or jurisdictional boundary is incomplete, the output should be EXPERT_REVIEW rather than a fabricated clearance.

Table 2 structures this layered environment as a choice-of-authority matrix. It distinguishes federal HFC and refrigerant-management rules from consensus safety standards, adopted model codes, and local administrative workflows, thereby avoiding the inaccurate assumption that all layers form a simple hierarchy or that every difference constitutes legal conflict.

Table 2. Multi-Tiered Regulatory Conflict Framework in Mechanical Decarbonization

Regulatory Domain	Legislative and Administrative Source	Governing Authority	Substantive Compliance Mandate	Municipal Conflict and Choice-of-Law Impact
Federal HFC and Refrigerant Rules	AIM Act; 40 C.F.R. pt. 84; CAA § 608 and 40 C.F.R. pt. 82	U.S. Environmental Protection Agency	Sector-specific HFC and GWP restrictions and dates; separate handling, recovery, anti-venting, certification, and recordkeeping duties	Does not mandate one named A2L refrigerant; dates and exceptions depend on product or system category
National Safety and Equipment Standards	ASHRAE 15; ASHRAE 34; UL 60335-2-40	Standards Development Organizations	Classification and engineering controls for lower-flammability refrigerants	Generally become legally operative through incorporation, listing, contract, or code adoption
State or Locally Adopted Mechanical Codes	IMC; IRC; state codes; local amendments	State and local adopting authorities / AHJs	Installation, ventilation, equipment, documentation, and safety requirements	Different editions and amendments can create implementation lag or additional review
Local Permitting and Licensing Workflows	Municipal ordinances; county codes; agency procedures	Village, city, county, or special-purpose authority	Registration, permit type, fees, plan review, inspection, and closeout	Address-specific micro-boundaries can change the competent agency and workflow

Note. Federal rules regulate particular substances, products, systems, and handling activities; they do not universally prescribe one A2L refrigerant. Local code lag may create uncertainty or additional review, but the existence of an actual conflict must be established from the governing texts and current agency guidance.

3. Geospatial Choice-of-Law Modeling and Boundary Resolution Topology

Regulatory compliance begins by resolving a physical parcel to the government entities with authority over the relevant activity (Bentlyewski, 2020; Salvino, 2022; Smith, 2018). Postal city names and ZIP codes are routing tools, not reliable jurisdictional boundaries. Thus, an address written as 'Schaumburg, IL 60173' may require verification against incorporated municipal limits and county boundaries before the applicable licensing, code, fee, and permitting workflow can be identified.

To resolve these spatial choice-of-law questions, the proposed architecture would use a deterministic multi-stage spatial resolution pipeline (Ford et al., 2026; Han et al., 2025). First, unstructured addresses would undergo standardized parsing and validation, followed by forward geocoding that outputs a coordinate pair $(x, y) \in \mathbb{R}^2$ on the WGS84 ellipsoid. Second, the coordinate pair would be tested against sourced and versioned polygon layers for municipal boundaries $(M_1, M_2, \dots, M_n)$, county administrative zones $(C_1, C_2, \dots, C_k)$, and Extraterritorial Jurisdiction (ETJ) corridors $(U_1, U_2, \dots, U_m)$ (Bentlyewski, 2020; Smith, 2018). Third, spatial containment would be evaluated through a point-in-polygon (PiP) algorithm. For a coordinate point $P(x, y)$ and a closed polygon B defined by vertices $(v_1, v_2, \dots, v_m)$, the point P , the point

would be classified as interior when the selected containment test returns the defined relation; the ray-casting formulation used in this study is:

$$\text{Contains}(B, P) = \left(\sum_{i=1}^m \text{Intersects}(\text{Ray}(P), v_i v_{(i \bmod m)+1}) \right) \equiv 1 \pmod{2}$$

Vertex indices in the expression above are taken cyclically: the second endpoint of edge i is $v_{(i \bmod m)+1}$, so that edge m closes the ring on v_1 and no undefined vertex $v_{(m+1)}$ is referenced. Rings are assumed to be explicitly closed and consistently oriented before the test is applied.

For efficient evaluation of complex boundary multipolygons, an implementation may use hierarchical spatial indexes such as S2 cells or R-Trees, reducing the candidate geometry evaluated from $\mathcal{O}(N)$ to $\mathcal{O}(\log N)$.

The proposed jurisdictional resolver would apply the following deterministic hierarchy, subject to validation against official GIS and agency sources (Ford et al., 2026; Han et al., 2025): The hierarchy is evaluated in strict order of containment scope rather than by named locality: the coordinate is first tested against every validated municipal boundary polygon in the candidate set $M = \{M_1, \dots, M_n\}$ for the surrounding county or counties, and a county administrative layer is evaluated only once every municipal polygon in that set has returned a negative containment result. The Schaumburg, DuPage, and Cook sequence below is a worked instance of that general rule, not an exhaustive enumeration, because a coordinate falling outside the Schaumburg polygon may still lie inside another incorporated municipality of the same county.

- **Level 1 (Incorporated Municipality):** When $\text{Contains}(M_{\text{Schaumburg}}, P) = \text{True}$, the candidate AHJ is the *Village of Schaumburg Community Development Department*, subject to confirmation of the current permit category, adopted code, and agency workflow. The same containment test is applied to each municipal polygon in the candidate set; the Schaumburg polygon appears here only as the worked example.

- **Level 2 (County Administrative Overlay - DuPage):** When $\text{Contains}(M_{\text{Schaumburg}}, P) = \text{False}$ and $\text{Contains}(C_{\text{DuPage}}, P) = \text{True}$, the candidate AHJ is *DuPage County Building & Zoning*, after which the applicable Accela or other county workflow must be verified. This branch is reached only after every municipal polygon in the candidate set has returned a negative containment result.

- **Level 3 (County Administrative Overlay - Cook):** When $\text{Contains}(M_{\text{Schaumburg}}, P) = \text{False}$ and $\text{Contains}(C_{\text{Cook}}, P) = \text{True}$, the candidate AHJ is *Cook County Building and Zoning*, with current unincorporated-area requirements verified from county sources. This branch is reached only after every municipal polygon in the candidate set has returned a negative containment result.

- **Level 4 (Boundary Anomaly and Exception Handling):** If a coordinate lies outside validated layers, falls within a disputed or stale boundary, or produces conflicting agency results, the system returns UNCOVERED_JURISDICTION or EXPERT_REVIEW. It does not issue automated legal clearance (Li & Zhou, 2026).

Figure 1 formalizes the five-stage geospatial resolution pipeline. It should be read as a proposed architecture: address standardization, WGS84 geocoding, official boundary ingestion, spatial indexing and point-in-polygon testing, followed by authority classification and confidence-based escalation.

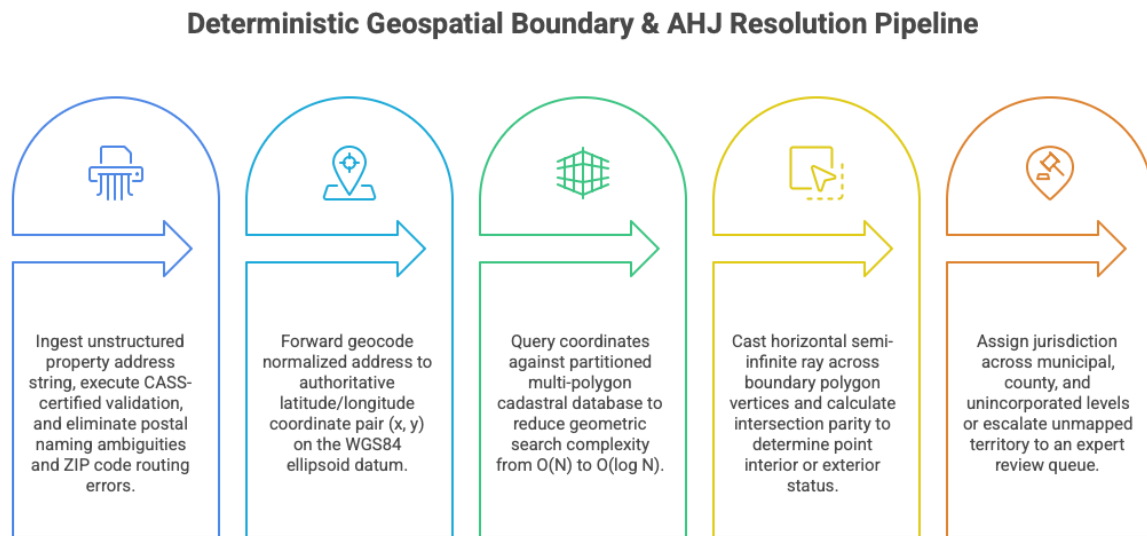


Fig. 1. Deterministic Geospatial Boundary and Authority Having Jurisdiction (AHJ) Resolution Pipeline

Note. The workflow traces the proposed progression from an unstructured address to a candidate administrative classification. CASS = Coding Accuracy Support System; WGS84 = World Geodetic System 1984; $O(N)$ / $O(\log N)$ = algorithmic complexity notation; PiP = Point-in-Polygon containment evaluation; and AHJ = Authority Having Jurisdiction. A candidate result is not final when layers are stale, incomplete, or contradictory; such cases are escalated to human review.

4. Evidentiary Provenance, Temporal Graphing, and Point-in-Time Reproducibility

Regulatory platforms used in construction and field services should generate records capable of supporting later administrative, insurance, or judicial review (Francesconi & Governatori, 2022; Krishnamurthy, 2025; Lassem et al., 2026; Zhang, 2025). Evidentiary value depends on more than storage format. The proponent must be able to explain how the record was created, what system generated or copied it, whether the process was reliable, who certified it, and whether required notice and other admissibility conditions were satisfied.

Within the Federal Rules of Evidence framework, the relevant distinctions include:

- **Rule 901 (Authenticating or Identifying Evidence):** Requires evidence sufficient to support a finding that the item is what the proponent claims it is; Rule 901(b)(9) provides an example involving a process or system that produces an accurate result.

- **Rule 902(13) (Certified Records Generated by an Electronic Process or System):** Allows authentication through a qualified person's certification that the process or system produces an accurate result, subject to the certification and notice requirements incorporated by the rule.

- **Rule 902(14) (Certified Data Copied from an Electronic Device, Storage Medium, or File):** Allows authentication of copied data through a digital-identification process and qualified certification; it authenticates the copy and does not establish the truth of every factual assertion contained in the data.

Accordingly, the proposed 'Rules-to-Evidence' pipeline is designed to preserve material that may support later authentication; it does not predetermine admissibility. Regulatory sources should be versioned and provenance-linked. Field workflows may capture geotagged and timestamped equipment images, refrigerant-handling records where required, instrument logs, technician credentials, signatures, and the identity of the person or process that created each artifact (Lassem et al., 2026; Liang, 2024; Sharma & Kunkel, 2026).

To prevent retrospective drift, a Temporal Regulatory Knowledge Graph would preserve the source, jurisdiction, effective date, supersession date, and verification history of each rule (Abdullayeva et al., 2025; Colombo et al., 2025; Amari, 2026; Baldwin & Ghanavati, 2026; Echenim & Joshi, 2025; Ershov, 2023; Garza et al., 2024; Joshi et al., 2020; Montiel-Ponsoda et al., 2017; Rodríguez Doncel & Ponsoda, 2020; Sovrano et al., 2020; Thakare, 2026). This enables a later reviewer to reconstruct what the system treated as applicable at the time of the job without silently substituting a newer code or fee schedule.

$$I_{\text{valid}} = [T_{\text{start}}, T_{\text{end}})$$

When a later audit examines a job performed at timestamp T_{job} , the proposed system would query the graph state satisfying $T_{\text{start}} \leq T_{\text{job}} < T_{\text{end}}$, while preserving later amendments as separate versions rather than rewriting the historical state (Abdullayeva et al., 2025; Colombo et al., 2025; Francesconi & Governatori, 2022; Thakare, 2026).

A resulting package could combine PDF/A, a structured JSON manifest, SHA-256 digests, signatures, source identifiers, and chain-of-custody events. These features can support integrity and authentication, but they do not by themselves make the contents accurate, satisfy hearsay exceptions, or guarantee admission. Rule 902(13) or 902(14) additionally requires an appropriate certification by a qualified person and compliance with the notice provisions incorporated through Rules 902(11) or (12) (U.S. Courts, 2017; LII, 2026). Table 3 maps field artifacts to the evidentiary functions they may support. The language is intentionally framed in terms of authentication support and provenance rather than automatic self-authentication or guaranteed admissibility.

Table 3. Evidentiary Standardization Matrix under Federal Rules of Evidence (FRE)

Compliance Package Artifact	Technical Data & Verification Properties	Relevant Evidentiary Rule	Substantive Legal and Administrative Value
Geotagged Visual Assets	Coordinate metadata, timestamp, device or source identifier, custody log	FRE 901(b)(9); potentially 902(13)/(14) with certification	May support proof of location, condition, and integrity; does not independently prove compliance
Refrigerant Handling Record	Cylinder identifier, measurements, technician identity, source-system log	FRE 901/902 as applicable; CAA § 608 records	May support handling and recordkeeping facts when the required regulatory fields and foundation exist
Technician Credential Snapshot	Dated registry extract, credential image or hash, employer attestation, source URL	FRE 901; potentially 902(13); other exceptions as applicable	Supports reconstruction of qualification status at the relevant time
Tamper-Evident Audit Package	PDF/A, JSON manifest, SHA-256 digest, signatures, custody events	Potentially FRE 902(13)/(14) with qualified certification and notice	Supports integrity and authentication; does not guarantee truth, hearsay exception, relevance, or admission

Note. The matrix identifies potential authentication pathways only. Actual admissibility remains case-specific and may require certification, notice, foundation, relevance, hearsay analysis, and judicial determination.

5. Administrative Due Process, Non-Delegation, and Human-in-the-Loop Governance

When an automated compliance system is incorporated into public permitting or enforcement, its design may implicate procedural due process, administrative accountability, and limits on delegating legally significant discretion (Dokumacı, 2024; Fortes et al., 2022; Lendvai & Gosztönyi, 2025; Rumlus, 2025; Yeung, 2018). A privately used contractor tool does not automatically exercise sovereign authority, but it can still shape access to work, customer outcomes, and the information presented to an agency. The governance question is therefore functional: what decision does the system make, whose authority does it represent, and what opportunity exists for review or correction?

For ambiguous, discretionary, or legally consequential determinations, the proposed architecture treats AI as a computational intermediary and decision-support mechanism rather than as an autonomous adjudicator (Cappelli et al., 2026; Casey, 2026; De Almeida et al., 2021; Li & Zhou, 2026; Onyekaonwu et al., 2024).

This boundary is implemented through layered controls that separate formalized constraints, probabilistic language processing, and accountable human authorization (Agarwal & Nene, 2025; Agarwal et al., 2025; De Almeida et al., 2021; Guo & Yiu, 2026; Outeda, 2024; Priya et al., 2026):

- **No Autonomous Final Adjudication:** The system may classify results as PASS, CONDITIONAL PASS, or EXPERT_REVIEW and may apply deterministic workflow stops to verified preconditions configured by authorized humans. It should not convert legal ambiguity into final agency approval or conceal a human override. Every warning, override, and source should be logged (Casey, 2026; Onyekaonwu et al., 2024; Singh, 2024).

- **Constrained LLM Architecture and Auditability:** Retrieval-Augmented Generation may locate, summarize, compare, and explain source material, but eligibility logic should be anchored in versioned rules and explicit uncertainty controls (Bharucha et al., 2026; Chung et al., 2025; Falcarin et al., 2025; Guo & Yiu, 2026; Hsia et al., 2025; Pont et al., 2025; Priya et al., 2026; Yang et al., 2026). Generative components may draft reports or communications; they should not silently transform incomplete or conflicting authority into a definitive clearance.

The architecture also provides a concrete bridge to the concepts of Metasubjectivity and cross-border electronic jurisdiction developed by Kostenko and colleagues (2022, 2024, 2025). The proposed system does not acquire legal personality and should not be described as a sovereign 'micro-jurisdiction.' Its metasubjective role is informational and coordinative: it assembles rules from multiple institutions, resolves context, models operational consequences, explains uncertainty, and records the path by which a human actor reached a decision. This interpretation is consistent with 'Code is Law' as a description of software's regulatory effects while preserving the distinction between technical enforcement, institutional authority, and legal validity.

The PersonaMatrix model developed by Drobakha and Zolotar (2024) adds a human-factors layer to this account. It models behavioral probability as a function of external stress load, internal conflict, and psychological resilience, providing a hypothesis-generating framework for studying how operators interact with dense regulatory interfaces:

$$P(\text{Behavior}) = f(\text{ESLI}, \text{ICC}, \text{PRL})$$

Where ESLI denotes the External Stress Load Index, ICC represents the Internal Conflict Coefficient, and PRL measures the Psychological Resilience Level. The formula supplies a conceptual model rather than proof of a causal relationship in HVAC work. It supports a testable human-factors sequence: regulatory complexity → cognitive load → uncertainty → stress → heuristic decision-making → compliance error. Under high regulatory friction and time pressure (ESLI ↑), the system should be evaluated for whether it reduces avoidable error and cognitive burden while preserving accountable human judgment and resilience (PRL ↑).

Figure 2 presents the layered Human-in-the-Loop (HITL) governance model. The base tier evaluates formalized rules and data constraints; the middle tier uses retrieval-grounded generative AI to explain sources, summarize requirements, and express uncertainty; the top tier reserves context-sensitive authorization and accountability for the qualified human actor. The figure is a conceptual allocation of functions, not a claim that deterministic code is infallible or that a cited model output is legally conclusive.

HITL AI Compliance Governance Architecture

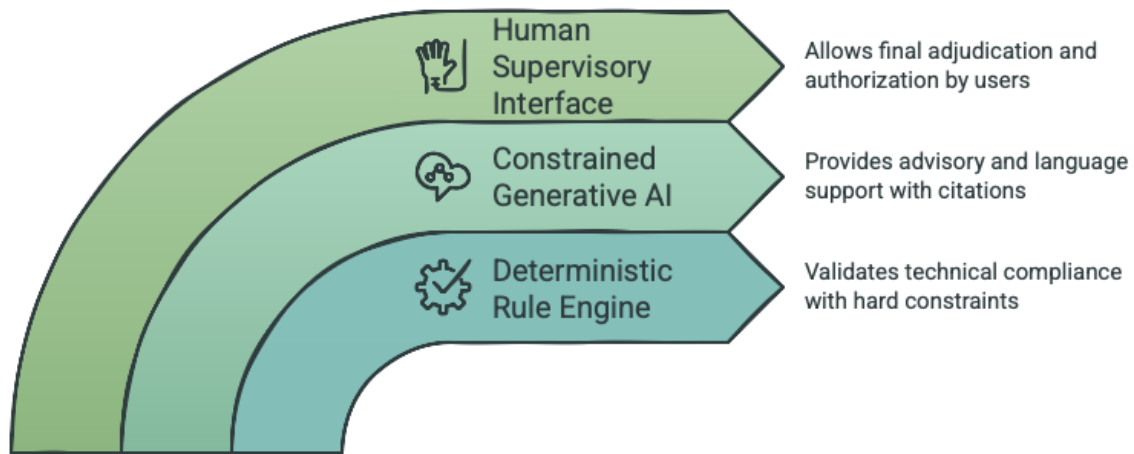


Fig. 2. Layered Human-in-the-Loop (HITL) AI Compliance Governance Architecture

Note. The layered architecture separates formal verification, constrained language assistance, and accountable human decision-making. Its purpose is to make uncertainty visible and reviewable rather than to present the system as a substitute for an AHJ, licensed professional, or court. System layers include:

- **Deterministic Rule Engine (Base Tier):** Evaluates formalized constraints, credentials, dates, and technical preconditions against versioned sources; exceptions and incomplete coverage remain visible.
- **Constrained Generative AI (Middle Tier):** Provides retrieval-grounded explanations, comparisons, transcription, and communication support with citations and uncertainty indicators; it does not grant legal approval.
- **Human Supervisory Interface (Top Tier):** Enables dispatchers, licensed contractors, reviewers, and public officials—according to their actual authority—to resolve ambiguity, authorize action, document overrides, and remain accountable.

5.1 From Physical Jurisdiction to Electronic Jurisdiction: Metaverse and AI Implications

The U.S. HVAC case represents an intermediate stage between territorial law and electronic jurisdiction. In the physical domain, a system maps an address and timestamp to a competent authority, an applicable code version, a licensed actor, and a permitted workflow. Once these elements are represented as versioned machine-readable objects, the system is no longer merely searching legal text; it is computationally reconstructing a jurisdictional state.

This progression may be stated as a continuum: physical jurisdiction → machine-readable jurisdiction → algorithmically mediated jurisdiction → electronic jurisdiction. The arrow does not imply that software creates legal authority. It identifies increasing levels of formalization through which institutional rules become queryable, executable in limited workflows, and explainable through AI.

Three subject positions coexist in this architecture. The human subject includes the technician, dispatcher, contractor, inspector, and customer. The institutional subject includes EPA, the state licensing body, the municipality, county, and AHJ. The algorithmic metasubject occupies a coordinating position across these actors by gathering rules, resolving context, modeling consequences, presenting uncertainty, and preserving an audit trail. Metasubjectivity here describes informational coordination, not legal personhood.

The analogy to the Metaverse is structural. In the U.S. field-service case, location + time + activity + actor determine the candidate legal and administrative regime. In a virtual environment, digital space + identity + transaction + platform rules + time determine the candidate governance regime. The same research questions

recur: who has authority, which rules prevail, how identity is verified, how decisions are explained, and how a point-in-time record can be reconstructed across borders or platforms (Kostenko et al., 2022, 2024, 2025).

AI serves four limited but significant functions across both environments: semantic interpretation of rule sources, context resolution, orchestration of heterogeneous data, and a natural-language interface between human actors and machine-readable governance. Its legitimacy depends on explicit uncertainty, source provenance, reviewability, and the preservation of human and institutional authority.

6. Enterprise Data Interoperability, RegTech Architectures, and Municipal API Topologies

Cross-jurisdictional regulatory intelligence requires interoperability with municipal portals and private Field Service Management (FSM) systems, but integration capability must be verified for each agency tenant, product plan, authorization scope, and endpoint (Celestin et al., 2026; Essien et al., 2025; Grassi & Lanfranchi, 2022; Kulkarni et al., 2021; Peddamallu, 2025; Pulikonda, 2025; Singh et al., 2026). The existence of a vendor developer portal does not prove that a particular municipality permits automated application submission or that all workflow actions are exposed through an API.

- **OpenGov (Village of Schaumburg, IL):** OpenGov provides a developer portal and API catalogue, but API access, endpoint coverage, and permission for automated permit submission must be confirmed for the specific agency tenant. The existence of an online Express Permit workflow does not by itself establish unrestricted API submission rights (OpenGov, 2026a, 2026b).

- **Accela Citizen Access (DuPage County, IL):** Accela documents REST APIs for Civic Platform resources, including records and documents. Whether DuPage exposes a particular endpoint, authentication mode, or write operation is agency-specific and requires technical confirmation (Accela, 2026).

- **Tyler Technologies EnerGov / WebPermit (Mecklenburg County / Charlotte, NC):** The platform supports permitting and land-management workflows, but integration capabilities, ArcGIS connections, mobile inspection functions, and external API access should be verified from current county and vendor documentation rather than assumed from product-level descriptions.

- **SHAPE PHX / PDD Online (City of Phoenix, AZ):** The portal supports online filing, plan-review tracking, and payments. The research architecture should initially treat it as an authenticated human-facing portal unless the City confirms a supported external API and the applicant's authorization to use it.

On the contractor side, Jobber documents a GraphQL API over HTTPS using OAuth 2.0, versioned headers, and webhooks. Housecall Pro documents a public API and webhooks, but access and feature coverage depend on the subscription plan and available endpoints (Jobber, 2026; Housecall Pro, 2026a, 2026b). Any proposed adapter should therefore begin with a capability and authorization audit rather than an assumption of full read-write access.

For sole proprietors without an external FSM, the architecture may include a minimal CRM module for customer records, scheduling, and basic invoicing. This remains a design option, not an existing deployed capability. Data separation and exportability should allow the module to be deactivated if the contractor later adopts Jobber, Housecall Pro, ServiceTitan, or another system without altering the historical compliance graph. Table 4 compares potential integration surfaces and explicitly distinguishes documented vendor capabilities from agency-specific availability that still requires verification.

Table 4. Integration Topology Across Municipal Portals and Commercial FSM Platforms

Platform Infrastructure	Primary Jurisdiction / Market	Architecture & Integration Maturity	API & Data Exchange Protocols	Permitting Workflow Capabilities
OpenGov	Village of Schaumburg, IL (candidate integration)	Cloud public-service platform; developer portal available	API catalogue and access controls; endpoint and tenant availability require confirmation	Online workflows documented; automated submission rights must be verified with the agency
Accela Citizen Access	DuPage County, IL (candidate integration)	Enterprise civic platform with documented REST APIs	REST/JSON resources and agency-specific authentication and configuration	Records, documents, reviews, and payments may be supported; actual county endpoints require confirmation
Tyler Technologies EnerGov	Mecklenburg County / Charlotte, NC (reference)	Enterprise permitting and land-management platform	Vendor- and agency-specific interfaces; GIS integration may be available	Permit, fee, licensing, and inspection functions vary by deployment
SHAPE PHX / PDD Online	City of Phoenix, AZ (reference)	Authenticated municipal portal	Treat as portal-first unless an external API is officially confirmed	Online filing, plan-review tracking, and payments; automation scope unverified
Jobber Developer Center	Commercial trade contractors (nationwide)	Documented developer platform	GraphQL over HTTPS, OAuth 2.0, version headers, webhooks	Customer and job data and scheduling integrations subject to scopes, review, and rate limits
Housecall Pro	Commercial trade contractors (nationwide)	Public API and webhooks documented; plan-limited	REST-style API documentation and signed webhook events; endpoint coverage varies	Custom integrations are possible, but not every product feature is exposed

Note. API availability, authentication method, endpoint coverage, pricing tier, and permission to submit or modify permit records must be confirmed with the vendor and the relevant agency before implementation.

7. Microeconomic Telemetry and Empirical Workflow Validation

Cross-jurisdictional fragmentation can impose disproportionate search, coordination, rework, and delay costs on small and medium mechanical contractors. The scale of this burden is an empirical question that should be measured through time-and-motion studies, permit records, reinspection data, administrative labor, and payment-cycle observations rather than inferred from industry anecdotes alone.

The iLION Digital portfolio data cited in the source materials offer an external cross-vertical automation benchmark, not evidence that the regulatory intelligence architecture described in this article has already

produced the same outcomes in HVAC permitting. Across five reported projects, the source dataset attributes the following portfolio-level changes to broader workflow and data-engineering interventions (Grandhi, 2024; Kothandapani, 2024; Liang, 2024):

- Reported inbound inquiry and job-processing throughput increased by +220.10% across the consolidated portfolio;
- Reported average operational Cost-Per-Acquisition declined to 80.15% of the stated pre-automation baseline;
- Reported monetary value of processed workflows increased by +225.42%;
- Reported net operational Return on Investment increased by +124.45%.

These figures should be used to formulate testable hypotheses, not to infer causal effects for HVAC compliance. Domain validation should separately measure AHJ-identification time, source-verification time, permit-package completeness, escalation rate, false-clearance rate, reinspection rate, administrative hours, technician-assignment errors, and payment closeout. Study designs should report sample size, baseline period, intervention period, data provenance, and confidence intervals. Table 5 therefore preserves the original comparison structure but recasts its automated values as pilot hypotheses and validation targets rather than realized production outcomes.

Table 5. Economic Delta and Operational Impact Matrix

Operational Parameter	Legacy Manual Process	Proposed Pilot Hypothesis / Target	Required Validation Evidence
AHJ and Rule Discovery	Manual search, portal review, and agency contact; baseline to be measured	Reduce median resolution time while preserving source traceability and escalation	Time logs, sample size, boundary-confidence data, source-verification rate, error analysis
Technician Assignment	Baseline credential-assignment error rate to be measured	Flag 100% of known rule or credential mismatches; report false-positive and false-negative rates	Credential source, assignment logs, overrides, confirmed violations, blinded review
Permit-Package Completeness	Baseline missing-field and rework rate to be measured	Increase first-submission completeness without claiming guaranteed approval	Permit samples, agency responses, completeness rubric, reinspection and revision records
Payment Closeout	Baseline days from work completion to administrative closeout or payment	Test whether faster documentation correlates with shorter closeout, controlling for permit type	Invoice dates, inspection dates, permit closeout dates, confounder analysis
Expansion to New Jurisdictions	Current research, legal-review, training, and integration cost per jurisdiction	Reduce reusable mapping effort while separately validating every new AHJ	Staff hours, external fees, rule coverage, exception rate, post-launch audit

Note. Values in the proposed-system column are research targets or illustrative hypotheses. They must not be reported as achieved results until supported by documented HVAC pilots, sample definitions, baseline measurements, and independently reviewable data.

8. Strategic Blueprint for Next-Generation Regulatory Intelligence Systems

Taken together, the U.S. cases support a research blueprint that integrates municipal authority analysis, federal environmental transitions, geospatial resolution, temporal provenance, constrained AI, human oversight, and interoperable public-private data systems (De Almeida et al., 2021; Essien et al., 2025; García-Llorente & Olmeda, 2026; Grassi & Lanfranchi, 2022; Mir-Hosseini et al., 2026; Rumlus, 2025). The blueprint is intentionally modular so that each claim can be separately verified and empirically tested.

Hierarchical Rule Engineering and Provenance

A regulatory knowledge graph should encode authority, subject matter, territorial scope, effective period, preemption relation, amendment history, and source provenance rather than assume that every rule fits a simple federal-to-state-to-local hierarchy (Joshi et al., 2020; Montiel-Ponsoda et al., 2017; Qiang, 2026; Thakare, 2026; Owolabi, 2025; Turaga et al., 2025; Yu et al., 2025). Federal environmental rules may control one issue while a state licensing rule and a local building code govern different aspects of the same job.

Spatial Containment over Postal Heuristics

AHJ resolution should use official municipal and county boundary data and point-in-polygon methods rather than ZIP-code heuristics (Bentleyewski, 2020; Salvino, 2022). Boundary version, source date, geocoding confidence, and exceptional overlays must be recorded. Ambiguous results should be escalated rather than converted into a speculative jurisdiction assignment.

Structured Human-in-the-Loop Governance

AI should operate as an audited regulatory intermediary. Deterministic controls may enforce verified technical preconditions configured by authorized humans, while ambiguous legal interpretation and final external clearance remain reviewable and human-accountable (Cappelli et al., 2026; Casey, 2026; De Almeida et al., 2021; Rumlus, 2025; Yeung, 2018).

Evidentiary Standardization (FRE 902(13)/(14))

Field evidence should use consistent schemas, provenance metadata, cryptographic integrity checks, and documented custody events (Francesconi & Governatori, 2022; Krishnamurthy, 2025; Sharma & Kunkel, 2026; Zhang, 2025). These measures can support authentication and auditability, but evidentiary status still depends on certification, notice, relevance, hearsay rules, and the forum's determination.

Open Permitting API Harmonization

Public agencies and vendors should expand documented, permissioned, and standardized permitting APIs while preserving security, privacy, and agency control (Grassi & Lanfranchi, 2022; Kulkarni et al., 2021). Open interfaces can reduce duplicate entry and support portable audit records, but the architecture must accommodate agencies that provide only portals, exports, or manual review.

Figure 3 synthesizes the five-pillar conceptual architecture. It should be interpreted as a research and design blueprint—not as evidence of production deployment—linking authority-aware rule engineering, spatial containment, human-in-the-loop support, cryptographic provenance, and verified API integration around a regulatory intelligence core.

Regulatory Intelligence Architecture Impacts Compliance

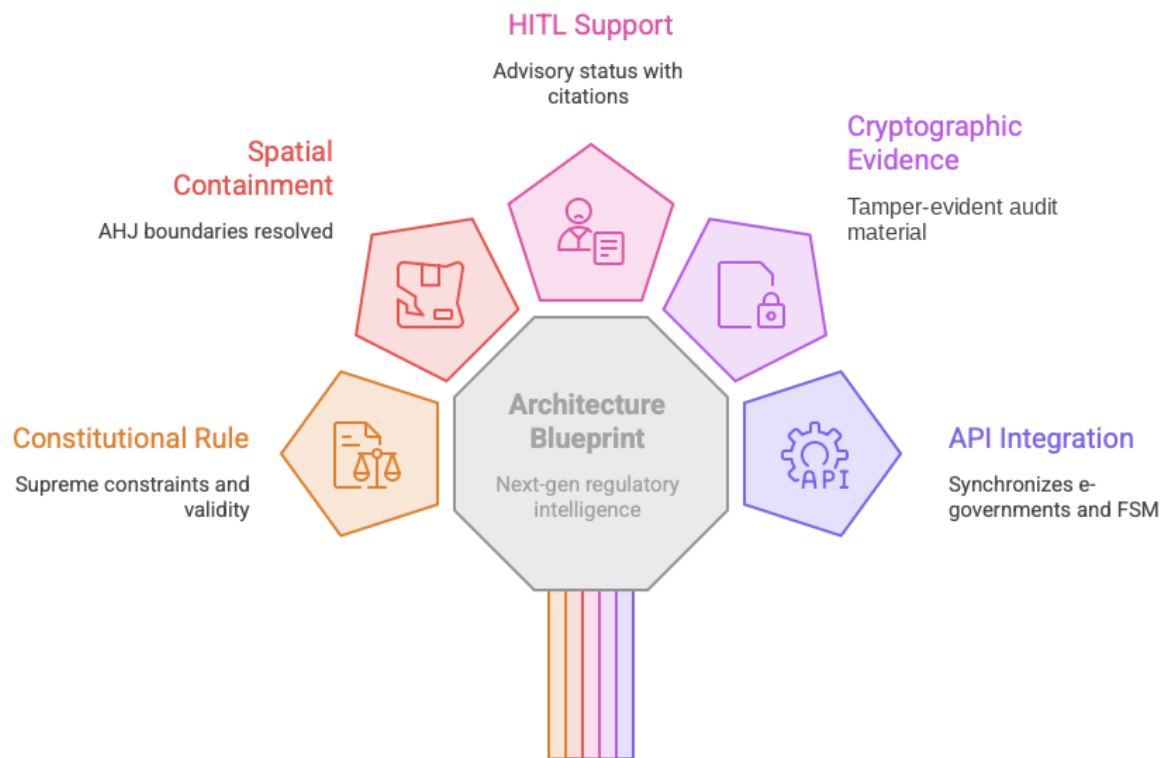


Fig. 3. Five-Pillar System Architecture Blueprint for Automated Regulatory Intelligence

Note. The radial blueprint identifies five functional pillars of the proposed regulatory intelligence architecture. Each pillar remains subject to primary-source verification, technical testing, and human governance:

- **Constitutional and Statutory Rule Engineering:** Represents authority, scope, preemption, effective dates, amendments, and primary-source provenance in a temporal graph.
- **Spatial Containment:** Resolves potential AHJs through official boundary layers, geocoding confidence, point-in-polygon analysis, and exception handling.
- **HITL Support:** Supplies explainable, source-linked recommendations while reserving authority and accountability for qualified human actors.
- **Cryptographic Evidence:** Creates tamper-evident audit material that may support authentication when accompanied by the required certification, notice, and chain-of-custody foundation.
- **Verified API Integration:** Synchronizes data only through documented, authorized, agency- and plan-specific interfaces, with manual fallback where APIs are unavailable.

Conclusions

The principal contribution of this study is the transition from law as a collection of texts to law as a spatially and temporally conditioned information structure with which users interact through constrained AI. The United States is particularly revealing because federalism, Home Rule, state preemption, local code adoption, and private permitting platforms expose the limits of a single national rule database.

HVAC is a proof domain rather than the outer boundary of the model. The same authority-resolution pattern may be tested in electrical and plumbing permits, occupational licensing, zoning, environmental approvals, drone operations, cannabis regulation, and local AI ordinances. Generalization must be demonstrated domain by domain; it cannot be assumed from the HVAC case.

Future research should combine legal source audits, GIS boundary validation, controlled retrieval tests, human-factors studies, and prospective contractor pilots. The decisive metrics are not only speed and cost, but

also source accuracy, temporal reproducibility, false-clearance rate, escalation quality, operator cognitive load, and the degree to which human accountability remains intelligible. These measures connect U.S. operational experience to the broader study of AI-mediated and Metaverse governance without treating a conceptual architecture as a completed empirical deployment.

Conflict of Interest Disclosure

The PersonaMatrix model cited in Section 5 (Drobakha & Zolotar, 2024) was co-developed by Anatoliy Drobakha, CEO of Oplentia SC, LLC, the contracted development vendor for the platform architecture described in this paper. This relationship is disclosed in the interest of transparency. The model is presented as a hypothesis-generating framework only and is not used as independent empirical validation of the proposed system.

REFERENCES

1. Abdullayeva, S., Madadova, A., Abdullayeva, N., Madatov, K., Kazakbaeva, S., & Khabibullayeva, S. (2025). Ontology-guided legal NER and relation extraction for Uzbek statutes with a juridical knowledge graph. In *2025 IEEE XVII International Scientific and Technical Conference on Actual Problems of Electronic Instrument Engineering (APEIE)* (pp. 1–6). IEEE. <https://doi.org/10.1109/apeie66761.2025.11289325>
2. Agarwal, A., & Nene, M. J. (2025). A five-layer framework for AI governance: Integrating regulation, standards, and certification. *Transforming Government: People, Process and Policy*, 19(3), 535–555. <https://doi.org/10.1108/TG-03-2025-0065>
3. Agarwal, B., Jomraj, H. S., Kaplunov, S., Krolick, J., & Rojkova, V. (2025). *RAgulating compliance: A multi-agent knowledge graph for regulatory QA* (arXiv:2508.09893). arXiv. <https://doi.org/10.48550/arxiv.2508.09893>
4. Amari, A. (2026). Machine-readable knowledge representation of regulation text for governance applications. In *2026 International Symposium of Systems, Advanced Technologies and Knowledge (ISSATK)* (pp. 1–6). IEEE. <https://doi.org/10.1109/issatk69667.2026.11567025>
5. Baker, L. A., & Rodriguez, D. B. (2009). Constitutional home rule and judicial scrutiny. *Denver University Law Review*, 86(5), 1337–1424.
6. Baldwin, W., & Ghanavati, S. (2026). *Knowledge graph representations for LLM-based policy compliance reasoning* (arXiv:2604.27713). arXiv. <https://doi.org/10.48550/arxiv.2604.27713>
7. Bentlyewski, R. L. (2020). Small Town, Inc.: Mischief at the margins of municipal incorporation. *Fordham Law Review*, 89(4), 1471–1512.
8. Bharucha, D., Palanisamy, N., & Reddy, M. (2026). ReguQuery: An agentic framework for automated regulatory compliance analysis using retrieval-augmented generation. In *2026 6th Biennial International Conference on Nascent Technologies in Engineering (ICNTE)* (pp. 1–6). IEEE. <https://doi.org/10.1109/icnte66387.2026.11437450>
9. Briffault, R. (2018). The challenge of the new preemption. *Stanford Law Review*, 70(6), 1995–2027.
10. Briffault, R., Davidson, N., Diller, P. A., Fox, S., Reynolds, L., Scharff, E., Schragger, R. C., & Su, R. (2020). *Principles of home rule for the twenty-first century*. National League of Cities.
11. Cappelli, M. A., Bozovic, L., Di Marzo Serugendo, G., & Fernandez-Marquez, J. (2026). Evaluating GenAI for automated EU AI Act compliance against human experts. *Discover Artificial Intelligence*, 6(1), Article 1196. <https://doi.org/10.1007/s44163-026-01196-1>
12. Casey, D. (2026). Regulatory technologies and regulatory intermediaries: Converging regulatory responses to RegTech. *Journal of Comparative Policy Analysis: Research and Practice*, 28(2), 145–164. <https://doi.org/10.1080/13876988.2026.2641670>
13. Celestin, M., Vasuki, M., Dinesh, A., Khadir, K., Riyasdeen, S., & College, K. M. (2026). RegTech enabled automation transforming regulatory compliance and supervision in fintech ecosystems. *Adhyayan Journal*, 13(1), 93640. <https://doi.org/10.3126/aj.v13i01.93640>
14. Chen, X. (2020). *Home rule, local autonomy, and municipal government behavior* (Publication No. 099) [Doctoral dissertation, University of Kentucky]. UKnowledge. <https://doi.org/10.13023/etd.2020.099>
15. Chen, X. (2022a). How does local autonomy shape the revenues of small municipalities? Evidence from Illinois home rule municipalities. *Chinese Public Administration Review*, 13(2), 75–86. <https://doi.org/10.1177/15396754221104381>
16. Chen, X. (2022b). Local autonomy and service delivery: How does home rule shape the provision of local public services? *Public Management Review*, 26(1), 1–24. <https://doi.org/10.1080/14719037.2022.2039953>
17. Chen, X., & Sullivan, A. (2025). With or without you: Does local autonomy increase intergovernmental collaboration? *Public Management Review*, 28(8), 2067–2095. <https://doi.org/10.1080/14719037.2025.2535428>
18. Chung, J., Ko, R., Yoo, W., Onizuka, M., Kim, S., Kim, T.-W., & Shin, W.-Y. (2025). *GraphCompliance: Aligning policy and context graphs for LLM-based regulatory compliance* (arXiv:2510.26309). arXiv. <https://doi.org/10.48550/arxiv.2510.26309>

19. Colombo, A., Bernasconi, A., & Ceri, S. (2025). An LLM-assisted ETL pipeline to build a high-quality knowledge graph of the Italian legislation. *Information Processing & Management*, 62(3), Article 104082. <https://doi.org/10.1016/j.ipm.2025.104082>
20. De Almeida, P. G. R., Santos, C. D. D., & Farias, J. (2021). Artificial intelligence regulation: A framework for governance. *Ethics and Information Technology*, 23(3), 505–525. <https://doi.org/10.1007/s10676-021-09593-z>
21. Diller, P. A. (2017). Reorienting home rule: Part 2—Remedying the urban disadvantage through state constitutional reform. *Louisiana Law Review*, 77(4), 1045–1113.
22. Dokumacı, M. (2024). Legal frameworks for AI regulations. *Human Computer Interaction*, 8(1), 133. <https://doi.org/10.62802/ytst2927>
23. Drobakha, A., & Zolotar, O. (2024). Psychological research in metaverses: The PersonaMatrix model. In *Digitalization, Metaverse, Artificial Intelligence in the Context of Human and Individual Rights Protection in Ukraine and the World* (pp. 329–342). Scientific Research Institute of Informatics and Law.
24. Echenim, K. U., & Joshi, K. (2025). Automating IoT data privacy compliance by integrating knowledge graphs with large language models. *IEEE Access*, 13, 118438–118451. <https://doi.org/10.1109/access.2025.3586278>
25. Ershov, V. (2023). *A case study for compliance as code with graphs and language models: Public release of the regulatory knowledge graph* (arXiv:2302.01842). arXiv. <https://doi.org/10.48550/arxiv.2302.01842>
26. Essien, I. A., Cadet, E., Ajayi, J. O., Erigh, E. D., Obuse, E., Ayanbode, N., & Babatunde, L. A. (2025). Designing intelligent compliance systems for evolving global regulatory landscapes. *Gulf Journal of Advance Business Research*, 3(9), 157–172. <https://doi.org/10.51594/gjabr.v3i9.157>
27. Falcarin, P., Chowdhury, P., Carbone, E., Scantamburlo, T., Tripodi, R., & Vascon, S. (2025). Legal requirements compliance using NLP and knowledge graphs. In *2025 IEEE 33rd International Requirements Engineering Conference Workshops (REW)* (pp. 412–418). IEEE. <https://doi.org/10.1109/rew66121.2025.00060>
28. Ford, C., Rane, O., & Leavy, S. (2026). *Navigating global AI regulation: A multi-jurisdictional retrieval-augmented generation system* (arXiv:2604.25448). arXiv. <https://doi.org/10.48550/arxiv.2604.25448>
29. Fortes, P., Baquero, P., & Amariles, D. R. (2022). Artificial intelligence risks and algorithmic regulation. *European Journal of Risk Regulation*, 13(3), 357–372. <https://doi.org/10.1017/err.2022.14>
30. Fox, S. (2017). Home rule in an era of local environmental innovation. *Ecology Law Quarterly*, 44(3), 575–624. <https://doi.org/10.2139/ssrn.2916917>
31. Francesconi, E., & Governatori, G. (2022). Patterns for legal compliance checking in a decidable framework of linked open data. *Artificial Intelligence and Law*, 31(3), 445–464. <https://doi.org/10.1007/s10506-022-09317-8>
32. García-Llorente, C., & Olmeda, I. (2026). Algorithmic governance in banking: A comparative analysis of risk-based and accountability-oriented oversight. *Journal of Banking Regulation*, 27(1), 85–102. <https://doi.org/10.1057/s41261-026-00320-6>
33. Garza, L., Elluri, L., Kotal, A., Piplai, A., Gupta, D., & Joshi, A. (2024). *PrivComp-KG: Leveraging knowledge graph and large language models for privacy policy compliance verification* (arXiv:2404.19744). arXiv. <https://doi.org/10.48550/arxiv.2404.19744>
34. Grandhi, R. K. (2024). Real-time natural language processing for regulatory change management: Extracting obligations from SEC, FCA, and MAS filings. *Economic Sciences*, 14(2), 884–899. <https://doi.org/10.69889/hc2jp884>
35. Grassi, L., & Lanfranchi, D. (2022). RegTech in public and private sectors: The nexus between data, technology and regulation. *Journal of Industrial and Business Economics*, 49(3), 441–479. <https://doi.org/10.1007/s40812-022-00226-0>
36. Grumm, J. G., & Murphy, R. D. (1974). Dillon's Rule reconsidered. *The Annals of the American Academy of Political and Social Science*, 416(1), 120–132. <https://doi.org/10.1177/000271627441600112>
37. Guo, D., & Yiu, S. (2026). *ComplianceNLP: Knowledge-graph-augmented RAG for multi-framework regulatory gap detection* (arXiv:2604.23585). arXiv. <https://doi.org/10.48550/arxiv.2604.23585>
38. Gutierrez-Alvarez, E. (2026). *Superintending the city: An administrative law for home rule* (SSRN Scholarly Paper No. 6556082). Social Science Research Network. <https://doi.org/10.2139/ssrn.6556082>
39. Han, Y., Ceross, A., & Bergmann, J. H. M. (2025). *Standard applicability judgment and cross-jurisdictional reasoning: A RAG-based framework for medical device compliance* (arXiv:2506.18511). arXiv. <https://doi.org/10.48550/arxiv.2506.18511>
40. Hsia, Y.-S., Yu, F., & Jiang, J. (2025). Neuro-symbolic compliance: Integrating LLMs and SMT solvers for automated financial legal analysis. In *2025 2nd IEEE/ACM International Conference on AI-Powered Software (AIware)* (pp. 1–10). IEEE. <https://doi.org/10.1109/aiware69974.2025.00010>
41. Joshi, K., Elluri, L., & Nagar, A. (2020). An integrated knowledge graph to automate cloud data compliance. *IEEE Access*, 8, 148541–148555. <https://doi.org/10.1109/access.2020.3008964>
42. Kostenko, O., Furashev, V., Zhuravlov, D., & Dniprov, O. (2022). Genesis of legal regulation web and the model of the electronic jurisdiction of the Metaverse. *Bratislava Law Review*, 6(2), 21–36. <https://doi.org/10.46282/blr.2022.6.2.316>

43. Kostenko, O. V., Zhuravlov, D. V., Nikitin, V. V., Manhora, V. V., & Manhora, T. V. (2024). A typical cross-border Metaverse model as a counteraction to its fragmentation. *Bratislava Law Review*, 8(2), 163–176. <https://doi.org/10.46282/blr.2024.8.2.844>
44. Kostenko, O., Dniprov, O., Zhuravlov, D., Tykhomyrov, O., & Vladov, S. (2025). A new paradigm of Metaverse philosophy: From anthropocentrism to metasubjectivity. *Philosophies*, 10(6), Article 117. <https://doi.org/10.3390/philosophies10060117>
45. Kothandapani, H. P. (2024). Automating financial compliance with AI: A new era in regulatory technology (RegTech). *International Journal of Science and Research Archive*, 11(1), 040–051. <https://doi.org/10.30574/ijrsra.2024.11.1.0040>
46. Krishnamurthy, P. (2025). AI-driven regulatory compliance: Automating legal enforcement in the technology sector. *International Journal of Computer Engineering and Technology*, 16(1), 245–259. https://doi.org/10.34218/ijcet_16_01_245
47. Kulkarni, V., Sunkle, S., Kholkar, D., Roychoudhury, S., Kumar, R., & Raghunandan, M. (2021). Toward automated regulatory compliance. *CSI Transactions on ICT*, 9(2), 95–104. <https://doi.org/10.1007/s40012-021-00329-4>
48. Lassem, N. K., Song, F., & Ali, S. A. (2026). *The violation situation pattern: Persistent representation of compliance violations in knowledge graphs* (arXiv:2606.03326). arXiv. <https://doi.org/10.48550/arxiv.2606.03326>
49. Lendvai, G., & Gosztönyi, G. (2025). Algorithmic bias as a core legal dilemma in the age of artificial intelligence: Conceptual basis and the current state of regulation. *Laws*, 14(3), Article 41. <https://doi.org/10.3390/laws14030041>
50. Li, J., & Zhou, A. (2026). Multi-regulation RAG for AI product counsel: A legal governance framework for cross-border digital commerces. *Rule of Law Studies Journal*, 2(2), 225–241. <https://doi.org/10.64780/rolsj.v2i2.225>
51. Liang, P. (2024). Leveraging artificial intelligence in Regulatory Technology (RegTech) for financial compliance. *Applied and Computational Engineering*, 93(1), 114–128. <https://doi.org/10.54254/2755-2721/93/20240964>
52. Mead, T. (2019). Federalism and state law: Legal factors constraining and facilitating local initiatives. In *Handbook of local government administration* (pp. 45–68). Routledge. <https://doi.org/10.4324/9781315093239-3>
53. Mir-Hosseini, N., Shojaei, D., & Sabri, S. (2026). A systematic review of methods for interpreting building code regulations in automated compliance systems. *Building Research & Information*, 54(3), 112–134. <https://doi.org/10.1080/09613218.2026.2637965>
54. Moe, L. (2026). Are cities creatures of the state? Home rule, state preemption, and the contest over local governance. *Journal of Planning History*, 25(2), 184–191. <https://doi.org/10.1177/15385132261434963>
55. Montiel-Ponsoda, E., Rodríguez-Doncel, V., & Gracia, J. (2017). Building the legal knowledge graph for smart compliance services in multilingual Europe. In *Proceedings of the 13th International Conference on Semantic Systems* (pp. 15–17). Semantic Web Company. <https://doi.org/10.5281/zenodo.4710359>
56. Newcomb, K. (2021). Breaking up with Dillon: A practical call for Virginia state & local government law reform. *William & Mary Environmental Law and Policy Review*, 45(1), 247–278.
57. Nolon, J. (2020). *Death of Dillon's Rule: Local autonomy to control land use* (SSRN Scholarly Paper No. 3709379). Social Science Research Network. <https://doi.org/10.2139/ssrn.3709379>
58. Onyekaonwu, C. B., Igba, E., & Anyebe, A. C. P. (2024). Agentic AI for regulatory intelligence: Designing scalable compliance lifecycle systems in multinational tech enterprises. *International Journal of Scientific Research and Modern Technology*, 3(12), 934–948. <https://doi.org/10.38124/ijrsmt.v3i12.934>
59. Outeda, C. C. (2024). The EU's AI Act: A framework for collaborative governance. *Internet of Things*, 27, Article 101291. <https://doi.org/10.1016/j.iot.2024.101291>
60. Owolabi, I. O. (2025). Operationalizing ESG-as-Code: Automating ESG compliance and regulatory reporting pipelines using containerized AI workflows on Kubernetes–OpenStack infrastructure. *Algora*, 2(2), 60–75. <https://doi.org/10.63084/algora.v2i2.60>
61. Peddamallu, M. R. (2025). AI-powered compliance automation in financial services. *International Journal on Science and Technology*, 16(4), 9557–9570. <https://doi.org/10.71097/ijst.v16.i4.9557>
62. Pont, T. R. D., Galli, F., Sartor, G., & Contissa, G. (2025). “Lost in EU regulation? Don’t worry, AI found the obligation”: Extracting and representing legal obligations in the GDPR, the DSA, and the AI Act. In *Proceedings of the Twentieth International Conference on Artificial Intelligence and Law* (pp. 112–126). ACM. <https://doi.org/10.1145/3769126.3769260>
63. Priya, S. S., Pharasi, K., Kumar, P., Kumar, R., Bhutia, R., & Gupta, J. (2026). LLM and reinforcement learning hybrid for automated regulatory compliance monitoring and adaptive rulemaking. In *2026 1st International Conference on AI, Data Science, Cyber Security and Smart Manufacturing for Sustainable Development (ICADCS)* (pp. 569–573). IEEE. <https://doi.org/10.1109/icadcs70036.2026.11583730>
64. Pulikonda, N. K. M. (2025). Real-time regulatory intelligence framework: LLM-powered compliance automation for financial services. *World Journal of Advanced Engineering Technology and Sciences*, 15(2), 784–798. <https://doi.org/10.30574/wjaets.2025.15.2.0784>
65. Qiang, Z. (2026). *Ontology-compliant knowledge graphs* (arXiv:2603.21188). arXiv. https://doi.org/10.1007/978-3-031-43458-7_48

66. Radom, O. S., Menahem, G., Meydani, A., & Hananel, R. (2025). Centralization, local autonomy and municipal activism: A new framework for examining relations between central and local government. *Land*, 14(3), Article 587. <https://doi.org/10.3390/land14030587>
67. Richardson, J. J. (2011). Dillon's Rule is from Mars, home rule is from Venus: Local government autonomy and the rules of statutory construction. *Publius: The Journal of Federalism*, 41(4), 662–685. <https://doi.org/10.1093/publius/pjr030>
68. Rodríguez Doncel, V., & Ponsoda, E. M. (2020). LYNX: Towards a legal knowledge graph for multilingual Europe. *Law in Context: A Socio-Legal Journal*, 37(1), 129–144. <https://doi.org/10.26826/law-in-context.v37i1.129>
69. Rumlus, M. H. (2025). Governing AI: A narrative review of algorithmic accountability and legal frameworks. *Legalis: Journal of Law Review*, 3(2), 810–825. <https://doi.org/10.61978/legalis.v3i2.810>
70. Salvino, R. F. (2022). *Home rule, selectivity, and overlapping jurisdictions: Effects on state and local government size* (Publication No. 1061478) [Doctoral dissertation, Georgia State University]. ScholarWorks @ Georgia State University. <https://doi.org/10.57709/1061478>
71. Sharma, A. K., & Kunkel, J. M. (2026). Ontological knowledge blocks: Executable compliance and profile-based validation for trustworthy AI systems. In *2026 IEEE 50th Annual Computers, Software, and Applications Conference (COMPSAC)* (pp. 2537–2542). IEEE. <https://doi.org/10.1109/compsac69091.2026.00379>
72. Singh, P. (2024). Using AI to navigate cross-border regulatory complexities in FinTech. *International Journal of Leading Research Publication*, 5(1), 1596–1610. <https://doi.org/10.70528/ijlrp.v5.i1.1596>
73. Singh, R., Pareek, M., Prokle, M., Sánchez, E., Hohgrawe, U., & Auclair, J. (2026). Federating AI-related regulations for human therapeutics: An AI-enabled, continuously updating regulatory intelligence system. *Frontiers in Drug Safety and Regulation*, 6, Article 1718379. <https://doi.org/10.3389/fdsfr.2026.1718379>
74. Smith, R. M. (2018). The process of municipal incorporation in the USA. In C. Nunes Silva (Ed.), *Local government and urban governance in Europe and North America* (pp. 17–37). Springer. https://doi.org/10.1007/978-3-319-72188-0_2
75. Sovrano, F., Palmirani, M., & Vitali, F. (2020). Legal knowledge extraction for knowledge graph based question-answering. *Frontiers in Artificial Intelligence and Applications*, 334, 143–153. <https://doi.org/10.3233/faia200858>
76. Stahl, K. A. (2015). Local home rule in the time of globalization. *BYU Law Review*, 2016(1), 177–260.
77. Stahl, K. (2024). *Home rule immunity from state preemption of local land use regulation* (SSRN Scholarly Paper No. 4400009). Social Science Research Network. <https://doi.org/10.2139/ssrn.4400009>
78. Swanson, J., & Barrilleaux, C. J. (2018). State government preemption of local government decisions through the state courts. *Urban Affairs Review*, 56(2), 671–697. <https://doi.org/10.1177/1078087418783273>
79. Thakare, K. (2026). Hybrid explainable AI and knowledge graph framework for dynamic multi-jurisdictional privacy law compliance. *International Journal for Research in Applied Science and Engineering Technology*, 14(3), 80854. <https://doi.org/10.22214/ijraset.2026.80854>
80. Turaga, V. S. P., Pahi, T., Tjoa, S., Siami-Namini, S., & Namin, A. S. (2025). CO2 (Co-Compliance Officer): An LLM-based ontology-driven methodology for generating knowledge graphs and AI compliance checking. *IEEE Access*, 13, 210576–210606. <https://doi.org/10.1109/access.2025.3639228>
81. Vasil, S. M., & Maxhelaku, A. (2026). The application of knowledge graphs in legal decision processes. *European Journal of Computer Science and Information Technology*, 14(5), 20–29. <https://doi.org/10.37745/ejcsit.2013/vol14n52029>
- Walshe, M. (2019). *Does local government autonomy promote fiscal sustainability? Lessons from Illinois's home-rule municipalities* [Doctoral dissertation, Northern Illinois University]. ProQuest Dissertations Publishing.
82. Yang, S., Bian, X., & Tang, J. (2026). *RegGuard: AI-powered retrieval-enhanced assistant for pharmaceutical regulatory compliance* (arXiv:2601.17826). arXiv. <https://doi.org/10.48550/arxiv.2601.17826>
83. Yeung, K. (2018). Algorithmic regulation: A critical interrogation. *Regulation & Governance*, 12(4), 505–523. <https://doi.org/10.1111/rego.12158>
84. Yu, M., Rabhi, F., Xia, B., Yang, Z., Tan, F., & Lu, Q. (2025). *OntoMetric: An ontology-guided framework for automated ESG knowledge graph construction* (arXiv:2512.01289). arXiv. <https://doi.org/10.48550/arxiv.2512.01289>
85. Zavydniak, V. I. (2025). Dillon Rule law and Cooley Doctrine law – Principles of local government in the United States and the election of certain government bodies and officials. *Scientific Journal "Regional Studies"*, 41, 7–18. <https://doi.org/10.32782/2663-6170/2025.41.7>
86. Zelasko, J. (2017). The reverse-commandeering system: A better way to distribute state and local authority. *Northwestern University Law Review*, 112(1), 83–120.
87. Zhang, T. (2025). A neuro-symbolic and blockchain-enhanced multi-agent framework for fair and consistent cross-regulatory audit intelligence. In *Proceedings of the 2025 International Conference on Digital Society and Intelligent Computing* (pp. 112–126). ACM. <https://doi.org/10.1145/3788910.3788948>
88. Zhu, X., Li, H., & Su, T. (2023). Autonomous complex knowledge mining and graph representation through natural language processing and transfer learning. *Automation in Construction*, 154, Article 105074. <https://doi.org/10.1016/j.autcon.2023.105074>

Primary Legal and Technical Sources

- Accela. (2026). Accela API documentation: Your first Accela API call. <https://developer.accela.com/docs/construct-firstApiCall.html>
- Housecall Pro. (2026a). API overview. <https://help.housecallpro.com/en/articles/8505035-api-overview>
- Housecall Pro. (2026b). How to enable webhooks. <https://help.housecallpro.com/en/articles/5683520-how-to-enable-webhooks>
- Jobber. (2026). Developer Center: About Jobber's API. <https://developer.getjobber.com/docs/>
- Legal Information Institute (LII). (2026). Federal Rule of Evidence 902. https://www.law.cornell.edu/rules/fre/rule_902
- OpenGov. (2026a). OpenGov Developer Portal overview. <https://developer.opengov.com/docs/overview>
- OpenGov. (2026b). Permitting & Licensing API catalog. <https://developer.opengov.com/catalog/public-service-platform-permitting-licensing>
- Occupational Safety and Health Administration (OSHA). (2024). Storage of pre-charged air conditioners and heat pumps in general industry. <https://www.osha.gov/laws-regs/standardinterpretations/2024-06-06>
- U.S. Courts. (2017). Amendments to Federal Rules of Evidence 902(13) and 902(14), congressional package and committee notes. https://www.uscourts.gov/sites/default/files/2017-04-27-congressional_package_rev._4-25_final_final_with_signed_letters_and_orders_1.pdf
- U.S. Environmental Protection Agency. (2026a). Technology Transitions HFC restrictions by sector. <https://www.epa.gov/hfcs/technology-transitions-hfc-restrictions-sector>
- U.S. Environmental Protection Agency. (2026b). Frequent questions on the phasedown of hydrofluorocarbons. <https://www.epa.gov/hfcs/frequent-questions-phasedown-hydrofluorocarbons>
- U.S. House of Representatives, Office of the Law Revision Counsel. (2026). 42 U.S.C. § 7675, American Innovation and Manufacturing Act of 2020. <https://uscode.house.gov/view.xhtml?edition=prelim&num=0&req=granuleid%3AUSC-prelim-title42-section7675%28a%29>