HYBRID QUANTUM COMPUTING

Benefits, Applications, and Strategic Considerations for Municipalities

A Comparative Analysis: Populations Above and Below 100,000

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Executive Summary

Hybrid quantum computing — systems that pair classical high-performance computing with quantum processors — is transitioning from research laboratories into practical, commercial deployment. While full fault-tolerant quantum computers remain on the 2030s horizon, today's hybrid systems already deliver measurable value in optimization, simulation, logistics, and cybersecurity.

Municipalities of all sizes stand to benefit from this technology, though the pathways to adoption, the priority use cases, and the investment requirements differ substantially based on population scale. Larger cities (populations above 100,000) have the complexity, data volume, and budget capacity to pursue direct or cloud-accessed hybrid quantum solutions for traffic management, emergency response coordination, energy grid optimization, and urban planning. Smaller municipalities (populations below 100,000) can leverage cloud-based quantum-as-a-service (QaaS) models, shared regional programs, and quantum-inspired classical algorithms to improve public services, resource allocation, and infrastructure maintenance at a fraction of direct acquisition cost.

This report outlines the spectrum of benefits, distinguishes the strategic approaches appropriate to each population tier, cites real-world case studies and pilot programs, and identifies leading organizations advancing municipal quantum applications.

1. What Is Hybrid Quantum Computing?

Hybrid quantum computing refers to architectures where quantum processors handle specific, computationally intractable sub-problems — typically optimization, sampling, or simulation tasks — while classical processors manage data preparation, workflow orchestration, error correction, and result interpretation. The two systems work in tandem, each contributing what it does best.

This hybrid approach is the dominant commercial model in 2026 because current quantum hardware, though powerful for targeted problems, still has limited qubit counts and error rates that make purely quantum computation impractical for most workloads. IBM's newly unveiled hybrid quantum computing architecture (March 2026) exemplifies this direction, combining quantum hardware with leading classical processing units, GPUs, high-speed networks, and shared digital storage.

1.1 Key Technologies and Vendors

Vendor / Organization	Technology Type	Key Offering for Government
IBM (Armonk, NY)	Gate-based quantum + classical hybrid	IBM Quantum Network; hybrid cloud architecture; Qiskit SDK
D-Wave Systems (Burnaby, BC, Canada)	Quantum annealing	Optimization problems; national security availability (2025)
Microsoft (Redmond, WA)	Topological qubits; Azure Quantum	Cloud quantum access; quantum-inspired optimization solvers

Vendor / Organization	Technology Type	Key Offering for Government
Google Quantum AI (Mountain View, CA)	Gate-based superconducting qubits	Quantum research; cloud hybrid services
Rigetti Computing (Berkeley, CA)	Gate-based; Quantum Cloud Services	Hybrid quantum-classical algorithms for optimization
Qilimanjaro Quantum Tech (Barcelona, Spain)	Quantum annealing chips	Smart city optimization use cases
QuSecure (San Mateo, CA)	Post-quantum cybersecurity	PQC migration pathways for government agencies

2. Cross-Cutting Municipal Benefits

Regardless of population size, hybrid quantum computing offers municipalities potential advantages across six foundational domains:

2.1 Traffic and Transportation Optimization

Traffic signal timing, route optimization, and public transit scheduling are combinatorial problems that scale exponentially with the number of intersections and vehicles. Quantum algorithms — particularly the Quantum Approximate Optimization Algorithm (QAOA) and quantum annealing — explore vast solution spaces simultaneously.

- Volkswagen partnered with D-Wave Systems to optimize traffic flow for fleets in Lisbon, Portugal and Barcelona, Spain using quantum annealing, demonstrating 17% improvement in travel times in pilot deployments.
- Siemens' Quantum-Assisted Traffic Flow Optimization initiative demonstrated up to a 35% reduction in average intersection wait times using hybrid quantum-classical algorithms.
- A 2019 simulation study in Japan projected a 40% reduction in city-wide congestion using quantum-driven traffic models.
- Microsoft and Ford explored quantum-inspired routing to deliver more balanced, less congestion-inducing navigation suggestions across vehicle fleets.

2.2 Emergency Response and Public Safety

Quantum computing's ability to simultaneously evaluate multiple variables — weather data, population density, infrastructure states, and resource availability — makes it powerful for emergency management:

- Optimal evacuation route planning during floods, fires, or chemical incidents, accounting for real-time road and population movement conditions.

- Dynamic dispatch optimization for fire, EMS, and police units to minimize response times across multiple simultaneous incidents.
- Crisis simulation and scenario modeling — allowing emergency managers to run thousands of 'what-if' scenarios to stress-test preparedness plans.
- Quantum Digital Twinning (U.S. Patent 12450677) is being explored for public safety management, creating real-time digital replicas of city infrastructure for crisis modeling.

2.3 Energy Grid and Utility Management

Modern municipal grids, incorporating distributed solar, EV charging, and bidirectional power flows, create optimization problems that exceed classical computing capacity in real time. Hybrid quantum approaches can:

- Optimize load balancing across the distribution grid to reduce peak demand charges and prevent outages.
- Improve preventive maintenance scheduling for critical infrastructure to maximize reliability and minimize service disruptions.
- Optimize water distribution networks to minimize waste and ensure equitable access across all service areas.
- IBM and Google quantum simulators have been tested on smart grid security using Quantum Physical Unclonable Functions (QPUF), achieving 86% key reliability.

2.4 Supply Chain, Logistics, and Fleet Management

Municipal governments manage complex logistics: waste collection routes, fleet maintenance schedules, procurement, and permit workflows. Quantum optimization delivers measurable operational improvements:

- Waste collection route optimization, reducing fuel consumption and labor hours.
- Quantum-enhanced fleet maintenance scheduling — the U.S. Postal Service has employed quantum technology to improve fleet maintenance planning and staff scheduling.
- Supply chain resilience modeling for emergency stockpiles, including medical supplies and disaster response equipment.
- Port of Los Angeles (SavantX + D-Wave): Optimizing truck-to-crane assignments at Pier 300 cut truck pickup times by up to two hours, raised container deliveries per crane by more than 60%, and generated millions in annual savings.

2.5 Cybersecurity and Post-Quantum Cryptography

Quantum computers will eventually break current public-key encryption (RSA, ECC). Municipal governments — which manage sensitive citizen data, financial systems, and critical infrastructure controls — must migrate to quantum-resistant cryptography before this occurs. This is the most pressing near-term quantum risk for all municipalities.

- NIST released the first three Post-Quantum Cryptography (PQC) standards in August 2024 (FIPS 203, 204, 205). All municipalities should begin cryptographic inventory and migration planning immediately.
- NIST IR 8547 mandates deprecation of quantum-vulnerable algorithms by 2035, with high-risk systems migrating much earlier. Municipal water control systems (SCADA), power grid controls, and financial platforms are in the high-risk category.
- CISA and DHS are actively working with state, local, tribal, and territorial (SLTT) partners on post-quantum readiness guidance and free assessment tools.
- QuSecure (San Mateo, CA) is collaborating with NIST's National Cybersecurity Center of Excellence (NCCoE) to develop post-quantum migration pathways for government systems as of 2026.

2.6 Urban Planning and Environmental Modeling

Quantum simulation enables municipalities to model complex urban and environmental scenarios with far greater fidelity than classical systems:

- Real-time analysis of multi-layer datasets (zoning, demographics, traffic, environmental sensors) to inform land-use decisions.
- Climate and flood modeling at hyper-local resolution to support resilience planning and infrastructure investment prioritization.
- Air quality and pollution dispersion modeling to support public health and environmental compliance programs.
- Research published in the journal Smart and Sustainable Built Environment (Taylor & Francis, 2025) highlights Quantum AI Urbanism as a transformative framework for future city planning.

3. Municipalities Above 100,000 Population

Large municipalities are the primary early adopters of hybrid quantum computing due to their scale, data complexity, budget capacity, and existing technology infrastructure. For cities like Dallas, TX; Chicago, IL; Phoenix, AZ; Seattle, WA; and comparable metros, the business case for quantum investment is clear and growing.

3.1 Why Scale Matters

Large cities generate exponentially more complex optimization problems than small ones. A city of 500,000 residents may have 200+ signalized intersections, multiple transit agencies, dozens of emergency dispatch zones, multi-hundred-mile water distribution networks, and terabytes of IoT sensor data daily. These problem sizes are precisely where quantum algorithms outperform classical approaches most dramatically.

3.2 Priority Use Cases for Large Municipalities

Use Case	Quantum Benefit	Example / Organization
Citywide traffic signal coordination	Real-time multi-intersection optimization impossible classically at scale	Volkswagen + D-Wave (Lisbon, Portugal; Barcelona, Spain)
Emergency response dispatch	Multi-variable simultaneous scenario evaluation for dynamic resource deployment	Smart city pilots; U.S. Patent 12450677 (quantum digital twinning)
Port and freight logistics	Crane/truck assignment optimization at large scale	Port of Los Angeles + SavantX + D-Wave (Los Angeles, CA)
Energy grid load balancing	Distributed grid optimization incorporating EV and solar variables	IBM/Google QPUF smart grid research
Large-scale urban planning	Multi-dataset scenario simulation across complex systems	Quantum AI Urbanism research, Taylor & Francis (2025)
Post-quantum cybersecurity migration	Protect large networks of critical infrastructure and citizen data	NIST NCCoE + QuSecure; CISA SLTT guidance

3.3 Implementation Pathways for Large Cities

- Direct cloud-based access via IBM Quantum Network, Microsoft Azure Quantum, or Amazon Braket — eliminating hardware acquisition costs while accessing enterprise-grade quantum systems.
- Hybrid QaaS contracts with vendors like D-Wave, Rigetti, or Qilimanjaro for specific, well-defined optimization problems with defined ROI metrics.
- University and national laboratory partnerships: Chicago can partner with Argonne National Laboratory (Lemont, IL); Los Angeles with Lawrence Livermore National Laboratory (Livermore, CA); Dallas-Fort Worth with Sandia National Laboratories.
- Participation in IBM's Quantum Network or the Quantum Economic Development Consortium (QED-C) to access technical resources and use-case development support.
- Appointment of a Chief Quantum Officer (CQO) or quantum technology lead within city IT departments — a model already adopted by several U.S. federal agencies.

3.4 Budget and Investment Context

The U.S. government awarded IBM and other firms $2 billion in quantum computing grants in May 2026, with smaller firms such as D-Wave and Rigetti each receiving up to $100 million. Large city governments should track these federal grants for potential partnership, cost-sharing, and pilot program eligibility.

Cloud-based QaaS models make direct quantum hardware ownership unnecessary. Initial city investments are predominantly in workforce development, software integration, cybersecurity audits, and QaaS contracts — achievable within existing IT budgets for cities above 100,000 in population.

4. Municipalities Below 100,000 Population

Smaller municipalities — from mid-size cities of 50,000 to small towns of a few thousand residents — face different challenges: tighter budgets, smaller IT teams, limited data infrastructure, and fewer immediate optimization problems at quantum-relevant scale. However, several pathways make hybrid quantum benefits accessible to these communities as well.

4.1 Key Barriers for Small Municipalities

- Cost: Most direct quantum computing budgets are in the seven-figure range; fully integrated quantum systems start at $50 million or more. This is prohibitive for small and medium municipalities.
- Talent gap: Quantum computing requires specialized skills in quantum algorithms, linear algebra, and hybrid programming — expertise that is rare in small municipal IT departments.
- Problem scale: Many municipal optimization problems below a certain size threshold are already solvable by classical or quantum-inspired methods without direct quantum hardware.
- Organizational resistance and limited co-creation opportunities slow adoption in resource-constrained government environments.

4.2 Realistic Pathways for Small Municipalities

The most practical near-term approach for small municipalities is to benefit from quantum computing indirectly through:

- Quantum-inspired classical algorithms: Optimization methods derived from quantum principles but run on classical hardware. They provide meaningful improvements over traditional approaches at low cost and are already embedded in commercial software for routing, scheduling, and resource allocation.
- Shared regional quantum consortia: Multiple small municipalities pooling resources to access QaaS platforms jointly — analogous to regional 911 dispatch centers or shared IT services models. State governments can facilitate this structure.
- State and federal pass-through programs: The South Carolina Quantum Association (SC Quantum) and similar state-level quantum initiatives provide educational resources, pilot program access, and grant pathways to local governments of all sizes.
- Vendor-packaged quantum-enhanced products: Commercial applications for water utility management, fleet routing, and building inspection scheduling are embedding quantum optimization engines without requiring direct municipal quantum expertise.
- Post-quantum cybersecurity — the universally urgent action: Every municipality, regardless of size, must begin their PQC migration. CISA's free resources and NIST's published standards make this actionable at minimal cost. Failure to act exposes municipal systems to 'harvest now, decrypt later' quantum attacks.

4.3 Priority Use Cases for Small Municipalities

Use Case	Approach	Benefit
Post-quantum cryptography migration	NIST PQC standards + CISA guidance (no cost)	Protects all citizen data and infrastructure from future quantum attacks
Fleet and maintenance scheduling	Quantum-inspired optimization software	Reduced fuel costs, improved equipment uptime
Water network optimization	Quantum-inspired classical algorithms or shared QaaS	Reduced water loss, equitable pressure management
Emergency resource pre-positioning	Cloud QaaS or quantum-inspired modeling via consortium	Faster response times, optimized asset deployment
Grant and finance optimization	Quantum-inspired portfolio analysis tools	Improved capital planning and budget allocation decisions
Regional transit scheduling	Shared QaaS via regional COG consortium	Better on-demand transit in lower-density service areas

4.4 Model: Regional Quantum Shared Services (RQSS)

A compelling model for small municipalities is the Regional Quantum Shared Services (RQSS) approach, analogous to how small cities share animal control, code enforcement, or court services. Under this model:

- A regional council of governments (COG) or metropolitan planning organization (MPO) contracts with a QaaS provider on behalf of member municipalities.
- Member municipalities submit optimization problems (scheduling, routing, resource allocation) to a shared quantum workflow engine.
- Costs are allocated proportionally by population or usage.
- A shared Quantum Technology Officer (QTO) position provides expertise and implementation guidance to all member cities.

This model is particularly relevant in Texas, where COGs like the North Central Texas Council of Governments (NCTCOG — serving the Dallas-Fort Worth region) and the Alamo Area Council of Governments (AACOG — serving San Antonio region) already coordinate regional technology and infrastructure programs.

5. Comparative Analysis: Large vs. Small Municipalities

Dimension	Above 100,000 Population	Below 100,000 Population
Primary access model	Direct cloud QaaS; IBM Quantum Network; vendor contracts	Regional consortia; quantum-inspired software; state programs
Highest-value use cases	Traffic optimization, emergency dispatch, port/freight logistics, energy grid	PQC migration, fleet scheduling, water network, grant optimization
Investment level (near-term)	Mid five- to low seven-figures for QaaS + integration	Low to mid five-figures via shared consortia or software procurement
Talent requirement	Dedicated quantum technology officer; vendor support	Regional QTO; rely on state/COG resources and vendor products
Timeline to operational value	3-5 years for pilot results; immediate for PQC migration	Immediate for PQC migration; 5-10 years for direct optimization value
Greatest immediate risk	Quantum-vulnerable SCADA and critical infrastructure systems	Quantum-vulnerable citizen data systems and financial platforms
Key partners	IBM, D-Wave, Microsoft, national laboratories, QED-C	State quantum associations, CISA, NIST, regional COGs, QaaS vendors
Federal support pathway	$2B federal quantum investment (May 2026); DOE national labs	CISA SLTT program; NIST PQC standards; state pass-through grants

6. Key Organizations and Initiatives

6.1 Federal and Government Bodies

- National Institute of Standards and Technology (NIST) — Gaithersburg, MD: Published first three PQC standards (FIPS 203, 204, 205) in August 2024. Leads global post-quantum migration guidance through the NCCoE.
- Cybersecurity and Infrastructure Security Agency (CISA) — Arlington, VA: Leads the Post-Quantum Cryptography Initiative for SLTT governments. Provides free readiness assessments and migration tools.
- Department of Homeland Security (DHS) — Washington, D.C.: Coordinates with NIST on post-quantum transition guidance for critical infrastructure sectors.
- National Quantum Initiative (NQI) — quantum.gov: Federal coordination office overseeing U.S. quantum strategy, research funding, and workforce development across agencies.

- Quantum Economic Development Consortium (QED-C) — National: Consortium of industry, academia, and government enabling a robust quantum industry. Published transportation and logistics quantum use case analysis.

6.2 Industry Leaders

- IBM Quantum (Armonk, NY): Operates the IBM Quantum Network for enterprises and government. Unveiled a new hybrid quantum-classical architecture in March 2026. Received a share of the $2 billion U.S. federal quantum investment in May 2026.
- D-Wave Systems (Burnaby, BC, Canada): The first commercially deployed quantum annealer. Case studies include the Port of Los Angeles logistics optimization (with SavantX) and Volkswagen traffic management. Made annealers available for U.S. national security work in November 2025. Received up to $100 million from the May 2026 federal quantum investment.
- Microsoft Azure Quantum (Redmond, WA): Cloud platform providing access to multiple quantum hardware backends and quantum-inspired optimization solvers. Collaborated with Ford on fleet routing optimization.
- Siemens AG (Munich, Germany): Developed the Quantum-Assisted Traffic Flow Optimization initiative, demonstrating hybrid QAOA algorithms for real-time intersection management.
- SavantX (United States): Data analytics firm whose HONE Engine integrates with D-Wave quantum systems. Led the Port of Los Angeles quantum logistics optimization pilot.
- QuSecure (San Mateo, CA): Post-quantum cybersecurity firm collaborating with NIST NCCoE on government quantum-safe migration pathways as of 2026.
- Qilimanjaro Quantum Tech (Barcelona, Spain): Developing quantum annealing chips specifically targeting smart city and industrial optimization use cases.
- Rigetti Computing (Berkeley, CA): Gate-based quantum computing and cloud services. Received up to $100 million from the May 2026 federal quantum investment.

6.3 Research and Academic Institutions

- Argonne National Laboratory (Lemont, IL): DOE facility conducting quantum computing research in energy grid optimization and materials simulation. Accessible to Midwest municipalities.
- Lawrence Livermore National Laboratory (Livermore, CA): DOE facility with advanced quantum simulation and cryptography research. Relevant to West Coast municipalities.
- Quantum Algorithms Institute (QAI) — British Columbia, Canada: Published case studies on quantum port logistics, including the D-Wave/SavantX Port of Los Angeles project.
- South Carolina Quantum Association (SC Quantum) — South Carolina: State-level organization publishing applied quantum computing use case documentation supporting local government awareness and adoption.
- Brookings Institution — Washington, D.C.: Published policy analysis on quantum computing adoption pathways for government, recommending near-term preparation strategies while awaiting fault-tolerant systems.

7. Recommended Action Steps by Municipality Size

7.1 All Municipalities — Immediate Actions (Now through 2027)

- Conduct a cryptographic inventory of all municipal IT systems to identify quantum-vulnerable encryption algorithms.
- Register with CISA's Post-Quantum Cryptography Initiative and download NIST's PQC migration playbooks at no cost.
- Develop a phased PQC migration roadmap prioritizing high-risk systems (SCADA water/power controls, financial platforms, citizen record databases).
- Educate IT leadership and elected officials on the quantum threat and opportunity landscape using resources from NIST, CISA, and the National Quantum Initiative.

7.2 Large Municipalities (>100,000) — Near-Term Actions (2025-2028)

- Identify two to three high-value optimization problems (traffic management, emergency dispatch, utilities) and issue RFIs/RFPs for hybrid quantum-classical solution pilots.
- Apply to join the IBM Quantum Network or QED-C to access technical expertise and vendor partnerships.
- Explore partnerships with nearby national laboratories or universities for co-funded quantum pilot programs.
- Designate a quantum technology lead or officer within the city's IT or innovation department.
- Monitor federal quantum investment grants (DOE, DARPA, NSF) for municipal eligibility and apply through state intermediaries.

7.3 Small Municipalities (<100,000) — Near-Term Actions (2025-2028)

- Prioritize post-quantum cryptography migration — the most urgent and most accessible near-term action for all municipalities.
- Engage with the regional COG or MPO to explore a Regional Quantum Shared Services (RQSS) model with neighboring cities.
- Contact the state quantum association or state CIO office for quantum readiness guidance and available grant programs.
- Evaluate commercial software vendors for quantum-inspired optimization features in existing procurement categories (fleet management, GIS, scheduling).
- Track vendor-packaged quantum tools that require no direct quantum expertise and can be deployed within existing IT infrastructure.

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Appendix A: Quantum Computing Readiness Checklist for Municipalities

Action Item	Priority	Applicable To	Resource
Conduct cryptographic system inventory	Critical - Immediate	All municipalities	NIST NCCoE Playbook
Begin PQC migration for highest-risk systems (SCADA, financial)	Critical - Near-term	All municipalities	CISA PQC Initiative
Complete full PQC migration by 2030	High - Medium-term	All municipalities	NIST IR 8547
Assess optimization problems for quantum applicability	Medium - Near-term	Cities >100,000	IBM Quantum Network / QED-C
Issue RFI/RFP for hybrid quantum pilot program	Medium - Near-term	Cities >100,000	D-Wave, Siemens, Rigetti
Engage regional COG for shared quantum services model	Medium - Near-term	Cities <100,000	NCTCOG, AACOG, state COGs
Contact state quantum association for resources	Medium - Near-term	All municipalities	SC Quantum; state CIO offices
Evaluate quantum-inspired features in vendor software	Low-Medium - Ongoing	All municipalities	Commercial vendor negotiations
Designate internal quantum technology point of contact	Medium - Near-term	Cities >100,000	Internal / QED-C resources
Apply for federal quantum grants (DOE, NSF, DARPA)	Medium - Ongoing	All municipalities	grants.gov; quantum.gov