Innovative solutions in water management using AI & ML

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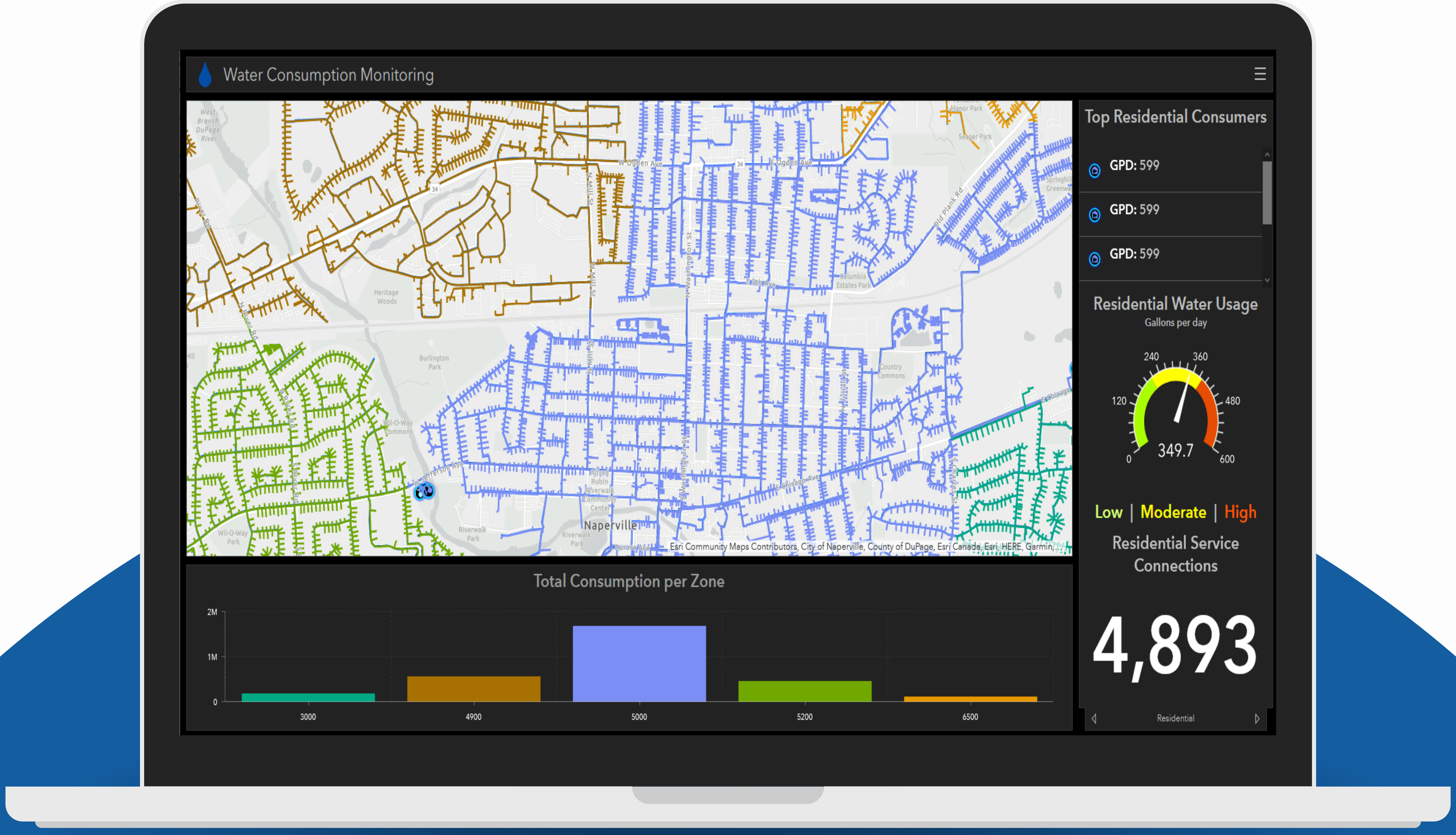
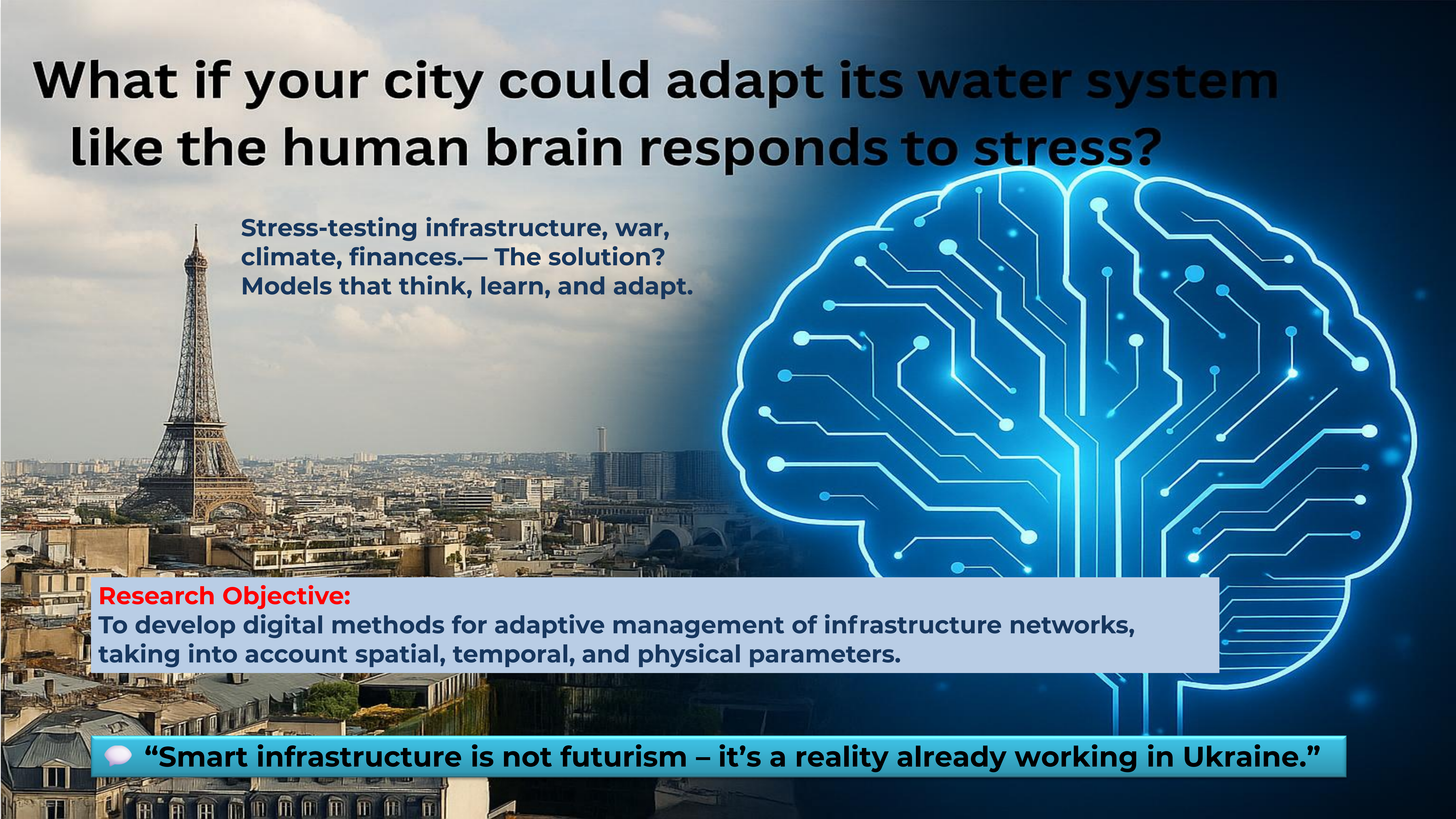


💬 **“We don’t just fix pipes — we teach the system to think.”**


What if your city could adapt its water system like the human brain responds to stress?
Stress-testing infrastructure, war, climate, finances.— The solution? Models that think, learn, and adapt.
Research Objective:
To develop digital methods for adaptive management of infrastructure networks, taking into account spatial, temporal, and physical parameters.
"Smart infrastructure is not futurism – it's a reality already working in Ukraine."

Real Problem

40% water loss

Damage caused by military actions

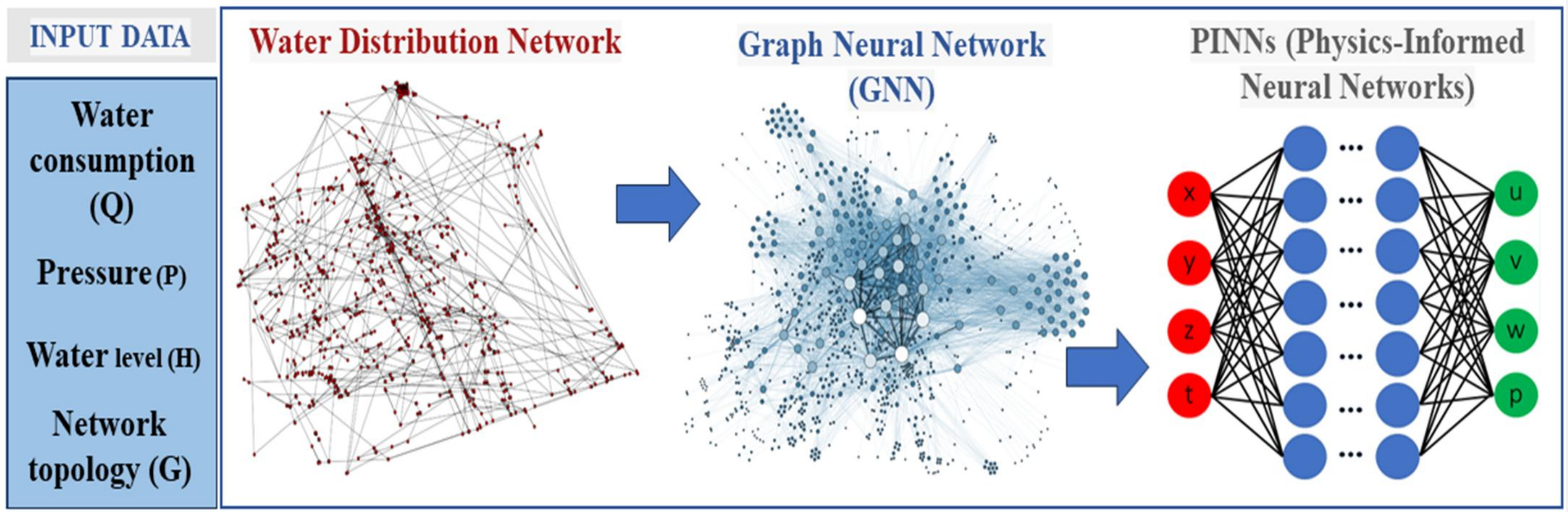
Aging infrastructure (60%)

Static and outdated planning

THE OLD SYSTEM CAN’T HANDLE THE NEW REALITY!

OUR SOLUTION:

Adaptive management of critical infrastructure networks based on hybrid models and spatial graph structures



Hybrid model = Spatial graph structures + Fuzzy GNN + PINN with physical laws + CMA-ES optimization + Geospatial data

💬 **“This is not just a forecast. It’s a digital strategy for the infrastructure of the future.”**

What is meta-intelligence for critical infrastructure?

01. Analytical capabilities

Intelligent data analysis for strategic decision-making.

02. System adaptation

Automatic adaptation to environmental changes (accidents, war, climate, consumption).

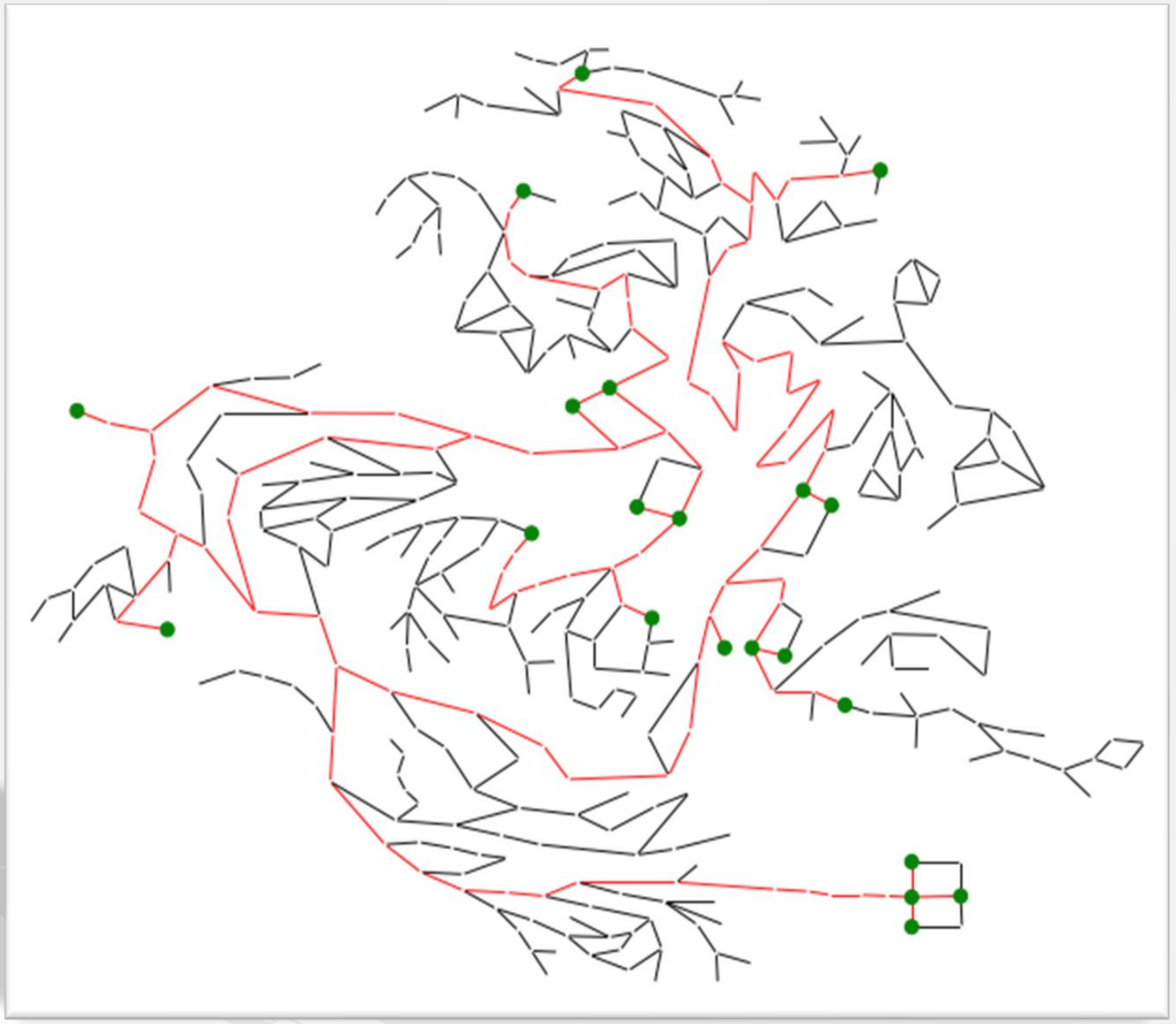
03. Neural knowledge network

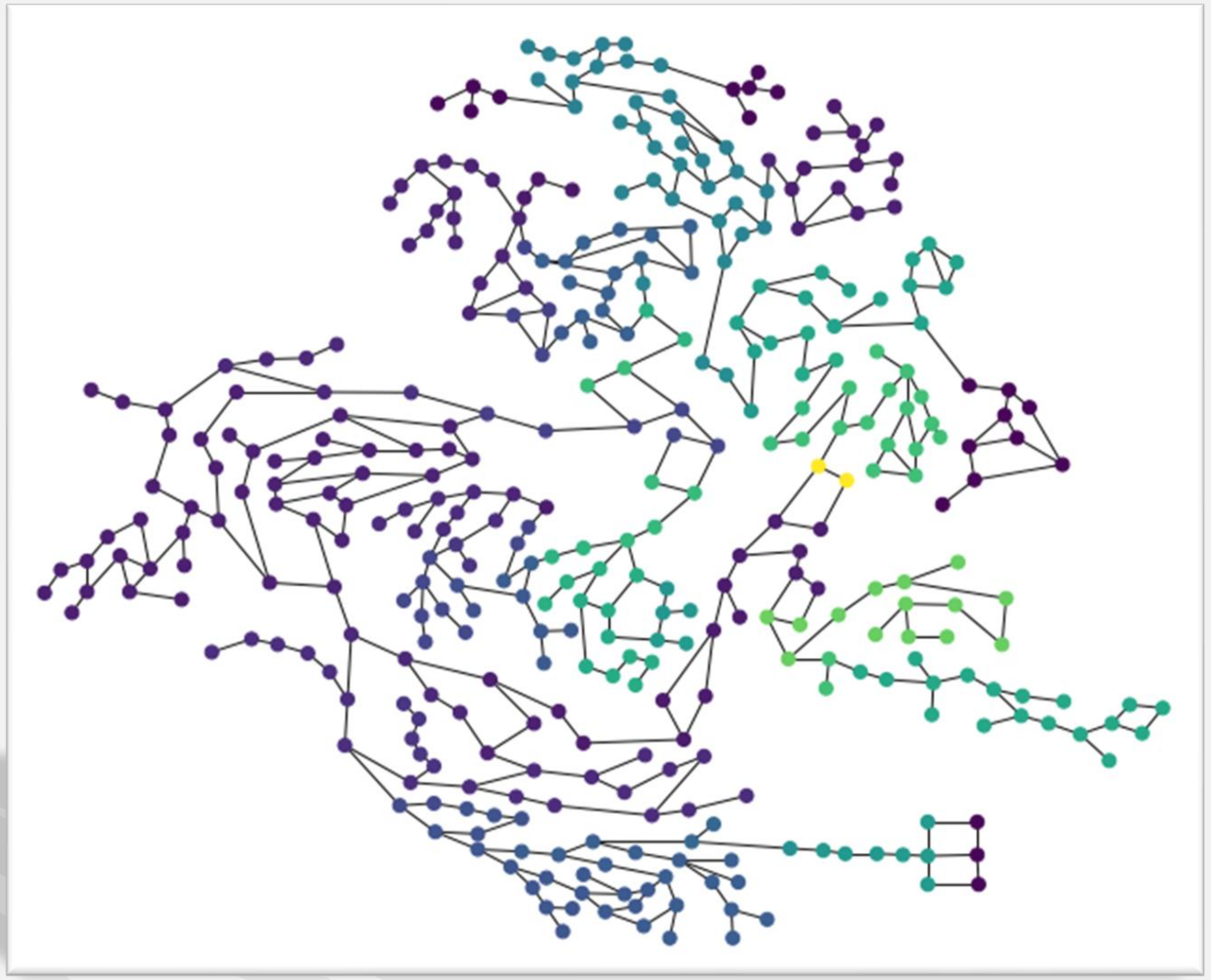
Self-learning graph models that combine historical, spatial, and physical data.

“Meta-intelligence is when Water supply company begins to act like a strategist: seeing the situation holistically, predicting the future, and making informed decisions without human intervention.”

Graph Model

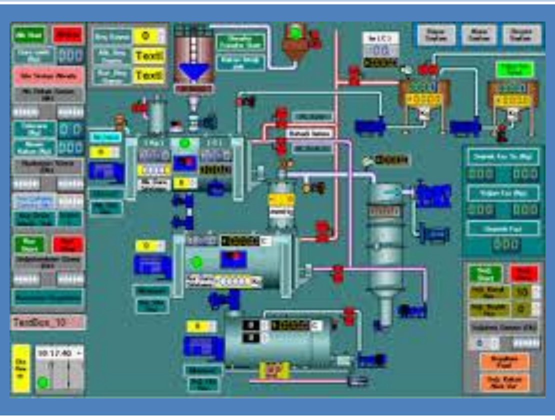
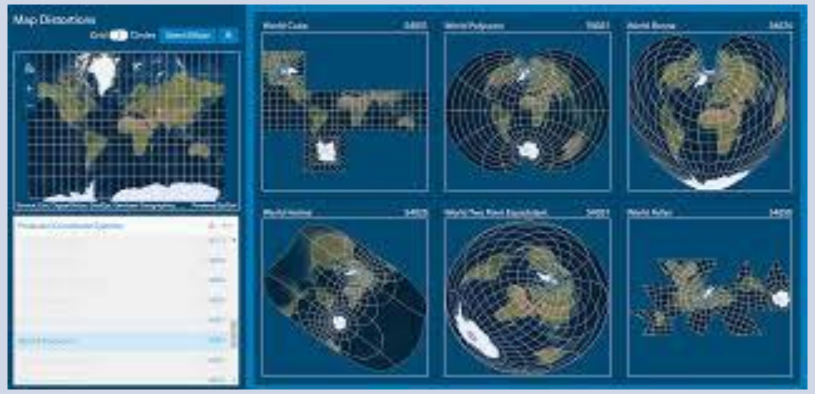
- ❖ Nodes – sensors / consumption points
- ❖ Edges – pipes, flows
- ❖ Weights – demand, pressure, failure probability





💬 **“A graph is the digital twin of a utility network.”**

Data & Sources

	**SCADA**
	**GPS / WGS-84 / Elevation**
	**Leak history**
	**Flows, pressure, consumption**

💬 **“Even without full SCADA — the model works. It learns from history and local data.”**

3 Scenarios of Adaptivity

Autonomous adaptation during and after attacks. Military-state resilience.

Wartime Conditions

Scenario simulation with repair prioritization. Energy consumption optimization.

Limited Budget

Demand forecasting. Efficiency-driven decision-making.

Smart Usage

"Your infrastructure acts strategically — like a chess player."

Comparison with Traditional Methods

Criterion	Traditional Methods	Adaptive Methods
Data Sources	Limited, often manual	Multi-layered: SCADA, GIS, leak history, geospatial attributes
Modeling	Helpless in crisis situations	Capable of modeling extreme events
Analysis	Manual analytics or simple algorithms	Automated analysis via GNN with fuzzy logic
Event Response	After the event occurs (reactive)	Predictive adaptation in real-time
Management	Static planning, rarely updated	Dynamic optimization using CMA-ES
Forecasting	Localized, limited	System-wide, considers spatial, temporal, and physical constraints
Maintenance Cost	High due to delayed decisions	Reduced via early problem detection and cost optimization
Scalability	Limited, requires significant manual adaptation	Flexible, easily adapts to new networks or scenarios

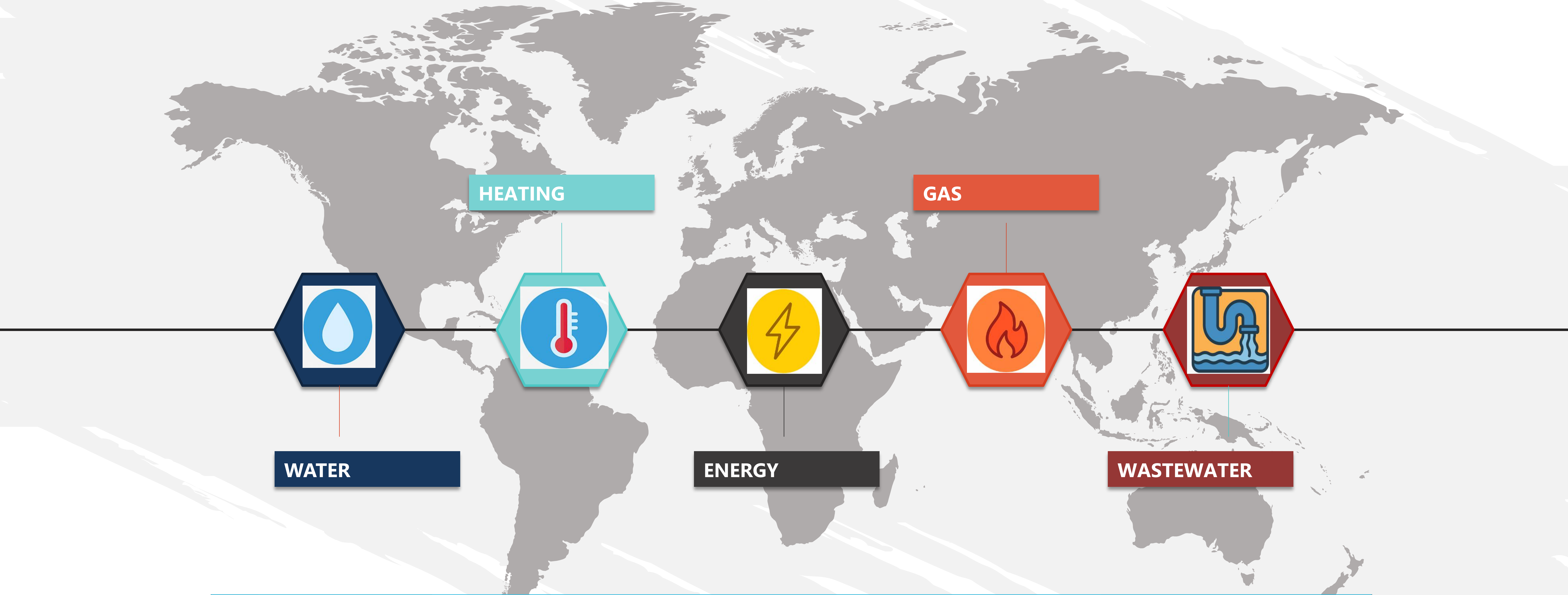
Practical Implementation

SCADA/IoT ⟷ **F-GNN-PINN** ⟷ **Planner**

We automatically detect losses.
The saved funds are directed to the modernization of treatment facilities.

💬 **"The model doesn’t just see — it proposes solutions."**

Scalability Potential



“Our algorithms can be applied across all infrastructure networks.”

Conclusions

- **An Adaptive Model:**
  Accounts for spatial, temporal, and physical constraints — acts as a strategist, not just an algorithm.
- **Real Savings and Impact:**
  Reduces losses, frees up resources, and optimizes infrastructure performance — even during wartime conditions.
- **Scalability:**
  Easily adaptable to other networks — heating, gas, energy — and aligned with Horizon Europe and Water4All goals.
- **Next-Generation Digital Twin:**
  Combines neural networks, hydraulic models, and geospatial analytics — forming the digital brain of the urban network.

💬 **"We built a new era of infrastructure AI to the sound of sirens."**

Wartime Conditions / Emergency Response

Goal: Rapid response when infrastructure is damaged or unstable

- ❖ Fast re-modeling of the water supply topology after disruptions (dynamic graph structure adaptation).
- ❖ Fuzzy GNN predicts high-risk zones — even with incomplete or missing data.
- ❖ PINN ensures physically accurate hydraulic simulation without full SCADA connection.
- ❖ CMA-ES optimization helps rebalance pressure and flow — where to direct water first?
- ❖ Can run on edge devices — no need for centralized online infrastructure.

💬 **“This isn’t just adaptation. This is resilience in the worst-case scenarios.”**

Limited Funding / Post-Crisis Management

Goal: Maximum impact with minimal investment

- Investment prioritization — the model identifies nodes where failures would be most costly.
- Phased implementation — simulate outcomes of step-by-step repair plans.
- What-if simulations — "What happens if we only replace 30% of the pipes?"
- Smart SCADA — activates automated leak detection only in high-risk zones.
- Learning from history — neural networks self-adapt to changing consumption patterns using historical data.

💬 **"Example: choosing between repairing a main pipeline or optimizing a pumping station."**

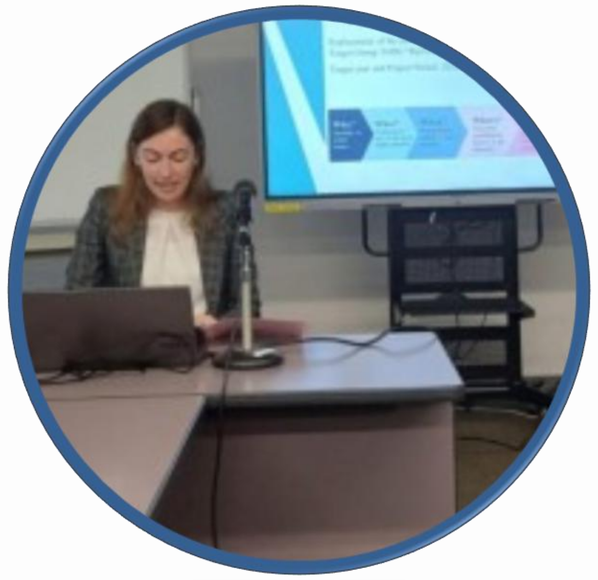
Smart & Sustainable Water Use

Goal: Resource optimization, transparency, and savings

- Individual dashboards for managing water use at the neighborhood level.
- Detection of inefficiencies — e.g., nighttime usage or abnormal consumption peaks.
- Integration with smart meters — neural networks learn from consumer behavior.
- Green optimization — reduce energy usage in pumping based on elevation, distance, and losses.
- Demand forecasting + weather adaptation = dynamic pump control in real time.

💬 **“Example: redirecting saved funds to upgrade water treatment facilities.”**

THANK YOU FOR YOUR ATTENTION!



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