Artificial intelligence and digitalisation for energy – a roadmap

1. Stakeholder Perspective and Policy Rationale

ZPP operates at the frontline of Europe's energy transition. We deploy assets, manage operational risk, invest in digital capabilities, and interface with consumers and prosumers. For us, digital tools are not abstract concepts but operational necessities such as advanced forecasting for variable renewables, grid visibility and condition-based maintenance, secure data exchange for new market services, and analytics for demand-side flexibility. A policy framework that accelerates these applications while ensuring trust, security, and fair competition will materially reduce system costs, improve reliability, and enable decarbonisation at the lowest cost to consumers. A central theme emerges from industry practice. Fragmentation of standards, market rules, data access regimes, and oversight responsibilities raises transaction costs and delays beneficial innovation. Conversely, clarity around interoperability, data usage rights, and proportionate compliance enables firms to scale solutions rapidly across jurisdictions. Addressing fragmentation and unlocking scale effects are, therefore, central priorities.

2. Accelerating Deployment: High-Impact Use Cases

In our assessment, three domains offer the highest near-term systemic benefits from digital and AI deployment:

1. **Power grid management.** Real-time observability, predictive maintenance, and algorithmic congestion management increase hosting capacity for renewables, defer capex, and reduce outage risks.

2. **Renewable energy integration.** Data-driven dispatch optimisation, advanced forecasting, and automated curtailment minimisation materially improve balancing efficiency and reduce renewable integration costs.

3. **Demand-side flexibility.** Dynamic pricing, automated demand response, and device-level orchestration unlock flexible load at scale, which is essential to accommodate electrification and variable generation.

3. Barriers and Enablers

From an implementation standpoint, several obstacles recur across projects and jurisdictions. Heterogeneous data models, device interfaces, and market messaging impede interoperability and portability, forcing vendors and operators into costly custom integrations. Limited access to high-quality and timely datasets, particularly grid and metering data under clear legal bases, constrains model performance and the viability of data-driven services. Divergent interpretations of data access, role definitions, and cybersecurity obligations slow deployment and create uncertainty for investors. Overcoming these issues requires coordinated European standards for interoperability, clearly defined data-access rights with robust privacy and security safeguards, and consistent guidance aligning energy-sector regulations with horizontal digital legislation such as the AI Act, the Data Act, the NIS2 Directive, the Cyber Resilience Act, and the GDPR.

4. European Energy Data Space: Governance and Design

A common European energy data space should be use-case driven, built upon agreed standards, and grounded in security by design. Governance should combine European-level oversight with structured participation from network operators, national authorities, standardisation bodies, and industry users. Such a structure would provide strategic coherence while preserving the practical adaptability required by evolving technologies and markets. Interoperability must rest on a shared set of open and commonly accepted data exchange standards and semantic models, supported by conformance testing and transparent versioning. Access should be role-based and supported by auditable consent mechanisms and legitimate interest flows, ensuring documented data provenance and measurable quality. Risk management should apply proportionate controls for privacy, confidentiality, and cybersecurity while maintaining differentiated access tiers and uniform incident-reporting procedures consistent with NIS2 requirements. The financing of shared infrastructure must follow a transparent cost-recovery model that encourages private investment and avoids vendor lock-in. This design resolves key challenges such as inconsistent regulation, poor interoperability, and tensions between openness and data protection, while maintaining a trusted, competitive environment.

5. AI in the Energy Sector: Foundation Models and Guardrails

While most existing value arises from conventional machine learning, foundation models can play a transformative role in forecasting, optimisation, anomaly detection, and natural-language interfaces for operational management. To capture these benefits responsibly, data environments used for training and development must be trusted, curated, and lawfully accessible. Datasets should be well documented, anonymised or pseudonymised where required, and supported by clear intellectual property and licensing conditions. Rigorous testing and validation are needed through energy-specific benchmarks that evaluate robustness, bias, and failure modes, accompanied by stress tests and red-team exercises. Access to computing resources should be efficient, transparent regarding energy consumption, and aligned with demand-response participation. In operational deployment, human oversight should be calibrated to system criticality, with traceable decision-making and defined fallback procedures to safeguard critical infrastructure.

6. Smart Grids and Digital Twins

Investment in smart and digitalised grids remains central to Europe’s security of supply and renewable integration. Operators face recurring budget constraints, complex integration between legacy and new components, and limited internal capacity to deploy and manage novel technologies. Overcoming these limitations depends on reducing investment risk, ensuring compatibility between systems, and strengthening operator expertise. Knowledge transfer programmes, common frameworks for system migration, and transparent interoperability testing will help operators deploy technology efficiently and safely. Digital twins can become an integral part of grid optimisation once observability of assets and access to edge data are improved. Their development should follow modular architecture principles, allowing expansion over time without replacing entire systems.

7. Integrating Data Centres Sustainably

The expansion of data centres across Europe presents both an opportunity for digital growth and a challenge for energy infrastructure. Rapid connection requests, concentrated demand clusters, and high energy intensity can cause local grid congestion and increase planning complexity. Sustainable integration requires early and continuous dialogue between developers and grid operators, supported by transparent data sharing and coordinated planning. National and regional grid development strategies must account for projected data centre growth to anticipate reinforcement needs. Locational incentives should direct projects toward areas with available capacity and proximity to renewable generation. Promoting operational flexibility, participation in demand response schemes, and hybrid grid connections with on-site renewables can reduce local congestion. Encouraging waste heat reuse and access to clean energy contracts will improve the sector's environmental performance while maintaining competitiveness.

8. Transparency, Risk Oversight, and Legal Guidance

Trust is indispensable for scale. Clear guidance on compliance and liability across legislative frameworks will encourage responsible adoption of digital and AI tools. Regulators should provide interpretative clarity on how the AI Act's provisions on high-risk systems interact with energy-sector use cases, how data processing aligns with GDPR and the Data Act, and how cybersecurity requirements under NIS2 and the Cyber Resilience Act apply to energy infrastructures. A transparent liability framework should define how responsibility is distributed along the AI value chain, ensuring that obligations are proportionate to the role and capacity of each actor, including SMEs. Sectoral safeguards co-designed with industry will standardise expectations of safety, interoperability, and accountability, supported by clearly documented procedures for human oversight and escalation in critical systems. Legal clarity will reduce uncertainty, facilitate replication of successful solutions across borders, and improve investor confidence.

9. International Cooperation and EU-Level Coordination

Energy systems are inherently cross-border, and technological supply chains are global. European action should therefore be embedded in wider cooperation. Exchanging best practices on the integration of AI into energy systems, including regulatory lessons and implementation approaches, will foster mutual learning and reduce duplication of effort. High-level orientations that link trustworthy AI principles with the specific needs of the energy sector will enhance consistency and credibility in the global dialogue on responsible digitalisation. Active participation in international standardisation initiatives will ensure that European companies can operate competitively without redundant compliance burdens. Within the Union, coordination should be strengthened through the creation of a dedicated expert group on AI in energy under existing structures, such as the Smart Energy Expert Group and a specific implementation working group within the SET Plan. Member States should align their Digital Decade Programmes and National Energy and Climate Plans to create a unified strategic direction.

10. Conclusion

Europe's energy transition depends on the responsible and widespread deployment of digital and AI technologies. The choices made in this policy framework will influence system efficiency, reliability, and competitiveness for years to come. Ensuring interoperability, transparent and lawful data access, proportionate risk management, and investment conditions that attract private capital will determine the success of this process. A coherent, predictable environment will reduce costs for operators, empower consumers, and strengthen European industry in a global technological race. ZPP remains ready to share practical expertise and to participate in the collaborative processes that will shape the European energy data space, standardisation work, and validation frameworks, ensuring that these policies translate into measurable benefits for businesses, consumers, and the wider economy.