State of Digital Twins for the Electricity Grid Across Europe – First iteration

Deliverable No: D3.1

Work Package: WP3

Funded by the European Union
Grant agreement ID: 101213413

DSO ENTITY DSOs FOR EUROPE

DSO4DT DSOs FOR DIGITAL TWINS

Disclaimer

Document Authors – TF DESAP
Stephan Gross
Omar Huarcaya
Ostins Gailis

Version	Date	Authors	Notes
0.1	22/01/2026	Ostins Gailis	Prepared first document structure.
0.5	18/02/2026	Stephan Gross	First working draft completed.
0.8	25/02/2026	Stephan Gross	Finalised first complete draft to be shared with DSO Entity's digitalisation experts.
1.0	16/03/2026	Stephan Gross	Integrating final feedback from DSO Entity's digitalisation experts.
1.1	21/05/2026	Stephan Gross	Prepare document for submission.

Document Co-Authors and Validators
Chair, Vice-Chairs, and Members of Task Force Digitalisation of the Energy System (TF DESAP)

Table of Contents

List of Abbreviations and Acronyms

Acronym	Meaning
DTA	Digital Twin Activities
DESAP	Digitalisation of the energy system
EC	European Commission
EU	European Union
DSO	Distribution System Operator
TSO	Transmission System Operator
JTF	Joint Task Force

Executive Summary

This deliverable presents a comprehensive baseline assessment of Digital Twin adoption at the distribution system operator level across Europe. Building upon the outreach activities and support needs assessment conducted in Work Package 1, this report synthesises insights gathered through stakeholder engagement, expert exchanges, and extended outreach activities within DSO Entity's established network.

The analysis follows a structured qualitative approach that acknowledges the diversity of the European DSO landscape and recognises that Digital Twin development evolves progressively. Rather than applying rigid benchmarking methodologies, the report identifies recurring patterns, strengths, structural constraints, and emerging trends that characterise the current state of Digital Twin deployment. The baseline assessment finds that Digital Twin adoption remains in very early development across most EU Member States, highly fragmented, and far from being a widespread operational reality. More advanced stages are limited to a very small subset of DSOs, a handful of outliers rather than an identifiable group, while genuinely federated or cross-DSO implementations are confined to a very limited number of DSOs representing isolated exceptions.

The functional understanding presented represents a synthesis of insights gathered during the first year of stakeholder engagement and expert exchanges. It identifies common elements across different initiatives and provides an analytical reference point that remains neutral, evidence based, and aligned with the objectives of the DSO4DT project as defined in the Description of the Action.

Key findings highlight that Digital Twin deployment at DSO level is not a singular technological project but an evolving transformation process. A foundational message of this report is that the Digital Twin is the integration, not the tool: it results from orchestrating processes, data, and models over time rather than from procuring a platform. Accordingly, near-term priorities should focus on foundational capabilities, data integration, observability, and modelling, with an increasing focus on delivering demonstrable operational value, while federated modelling concepts remain a longer-term horizon contingent on stable, validated, and internally consistent models that very few DSOs currently meet. The report prioritises pragmatic, achievable steps while maintaining a long-term perspective, and provides a foundation for subsequent iterations under Deliverables D3.2 and D3.3, which will build upon the progress observed and refine the roadmap accordingly.

1 Introduction

The DSO4DT project aims to support the development and adoption of Digital Twins among European DSOs through targeted outreach, needs assessment, and expert support activities. Following the initial outreach phase documented in Deliverable 1.1 and the first iteration of the Support Needs Assessment presented in Deliverable 1.2, this deliverable establishes a comprehensive baseline assessment of the current state of Digital Twin deployment at the distribution system.

The primary objective of this deliverable is to provide an evidence-based analysis of Digital Twin adoption across the European DSO landscape. This assessment builds upon the exchanges and support needs assessment conducted under Work Package 1, as well as insights gathered through extended outreach activities and expert discussions within DSO Entity's established working structures.

This deliverable focuses specifically on Digital Twin adoption at the distribution system. While interactions with TSOs, research initiatives, and standardisation bodies are essential for long term interoperability, the primary analytical perspective remains the capabilities, challenges, and development trajectories of DSOs.

The baseline assessment follows a structured qualitative approach that acknowledges the diversity of the European DSO landscape. The objective is not to rank or compare individual operators, but to identify recurring patterns, strengths, structural constraints, and emerging trends that characterise the current state of play. This ensures that the analysis remains neutral and provides a valuable reference point for understanding the evolution of Digital Twin deployment across different contexts and organisational maturity levels.

The findings presented in this deliverable will inform subsequent support activities under the DSO4DT project and contribute to the refinement of the roadmap for Digital Twin adoption. Subsequent iterations under Deliverables D3.2 and D3.3 will build upon the progress observed and further develop the analytical framework presented here.

2 Digital Twins for Distribution System Operators

2.1 Purpose and Methodological Positioning

Before assessing the state of Digital Twin adoption among European DSOs, it is necessary to clarify how the term Digital Twin is used within this report.

During the first year of the DSO4DT project, the project team deliberately refrained from imposing a predefined definition of Digital Twins. Instead, the approach taken under Work Package 1 was exploratory. The project sought to understand how stakeholders themselves, including Digital Twin Activities, DSOs, technology providers, and standardisation bodies, interpret and operationalise the concept in practice.

This methodological choice ensured that exchanges remained open and that the diversity of interpretations across the European ecosystem could be captured without shaping discussions through a predefined conceptual framework.

The functional understanding presented in this section is therefore not prescriptive. It represents a synthesis of the insights gathered during the first year of stakeholder engagement and expert exchanges. It identifies common elements across different initiatives and provides an analytical reference point for this deliverable.

This framing ensures that the subsequent baseline analysis remains neutral, evidence based and aligned with the objectives of the DSO4DT project as defined in the Description of the Action.

This deliverable focuses on Digital Twin adoption at the distribution system level. While interactions with TSOs, research initiatives, and standardisation bodies are essential for long term interoperability, the primary analytical perspective remains the capabilities, challenges, and development trajectories of DSOs.

The objective is not to evaluate individual operators. Instead, this report provides an aggregated European level assessment of readiness, strengths, and gaps. It establishes the conceptual foundation for the baseline analysis presented in the following section and for the initial roadmap and support framework defined under Work Package 3.

2.2 Functional Understanding of a Digital Twin in the DSO Context

Based on the insights gathered in Year 1, a Digital Twin of a distribution network can be functionally understood as:

> *A dynamic, data driven digital representation of relevant grid assets, processes, and system states that enables analysis, simulation, forecasting, and decision support across operational, planning, and resilience related time horizons.*

This understanding reflects several recurring characteristics observed across stakeholder discussions.

Integrated Data Foundation

Digital Twins rely on the structured integration of heterogeneous data sources, including SCADA systems, GIS models, smart meter data, asset databases, and external data streams such as weather information or market signals. Data quality, consistency, and interoperability form essential prerequisites.

Model Based Representation of Infrastructure

A Digital Twin includes network and asset models capable of performing load flow calculations, state estimation, contingency analyses, and scenario simulations. It provides a coherent digital representation of the physical distribution infrastructure.

Dynamic Behaviour and Forecasting

Unlike static digital records, a Digital Twin reflects current or near real time system states and enables forward looking simulations. It supports forecasting of load, generation, and flexibility potential under different assumptions and scenarios.

Decision Support Across Time Horizons

Digital Twins support:

- Short term operational decision making, such as voltage control and congestion management,
- Medium-term planning activities, including reinforcement needs and distributed energy resource integration,
- Long term infrastructure development and investment planning.

Contribution to Resilience and Security

Beyond operational optimisation, Digital Twins can contribute to strengthening the resilience and security of the distribution grid. By enabling a deeper and more integrated understanding of asset conditions, system behaviour, and interdependencies, they support:

- Improved contingency analysis and fault response strategies,
- Anticipation of stress scenarios related to extreme weather events or high renewable penetration,
- Enhanced cybersecurity awareness through structured modelling of system interconnections,
- More informed asset management and lifecycle planning.

In this sense, Digital Twins can be regarded as strategic tools to reinforce reliability, robustness, and long term system security at the distribution level.

Importantly, this report does not treat Digital Twins as a binary concept. Digital Twin development is understood as a continuum. DSOs may be at different stages along this continuum, depending on their technical maturity, regulatory environment, organisational capacity, and available resources.

2.3 Digital Twins and the Four Outcome Areas of the Project Call

The Horizon Europe call under which DSO4DT is funded defines four key outcome categories for Digital Twin development. These outcome areas provide a structure to assesses Digital Twin adoption among DSOs.

I. Strengthened Observability and Controllability of the Grid

Digital Twins enhance observability through the integration of near real time data from substations, smart meters, and sensors. Improved situational awareness supports faster fault detection, voltage management, and congestion mitigation.

When connected to active system management tools, Digital Twins also strengthen controllability by allowing DSOs to simulate potential control actions before implementation.

II. Optimised Infrastructure and Network Planning

By combining historical data, asset condition information, and scenario modelling, Digital Twins support evidence-based investment planning. They enable DSOs to simulate future load growth, distributed energy resource integration, and flexibility potential under different regulatory and market conditions.

III. Joint Modelling for a More Resilient Grid

Digital Twins provide an analytical basis for coordinated modelling across voltage levels and organisational boundaries. Interoperable data models and structured interfaces enable collaboration between DSOs, TSOs, and other relevant stakeholders.

This joint modelling capability directly contributes to system resilience by improving the understanding of interdependencies and stress scenarios affecting the broader electricity system.

IV. Increased Use of Active System Management and Forecasting

Advanced Digital Twins integrate forecasting models and enable proactive congestion forecasting, flexibility activation planning, and demand response integration. These capabilities support a more efficient utilisation of existing infrastructure.

2.4 Digital Twins in a System of Systems Context

In parallel to the DSO4DT project, DSO Entity and ENTSO E are jointly analysing the role of Digital Twins for the European electricity grid through a structured technical cooperation. The latest joint technical work adopts a use case driven and cross voltage level perspective on Digital Twin deployment.

This perspective complements the DSO focused framing above by introducing two additional dimensions.

Use Case Driven Development

The joint technical analysis emphasises that Digital Twin development should be anchored in clearly defined operational and planning use cases. Rather than conceptualising Digital Twins as abstract digital infrastructures, specific Digital Twin solutions are mapped to concrete system challenges, including:

- Congestion forecasting across voltage levels,
- Coordinated system restoration scenarios,
- Renewable energy integration pathways,
- Flexibility activation and market interaction,
- Cross voltage contingency analysis.

This approach underlines that Digital Twin architectures must remain purpose oriented and linked to clearly articulated system needs.

For this deliverable, this implies that assessing DSO readiness requires examining not only technical capabilities but also the clarity, prioritisation, and maturity of defined use cases within each DSO context.

Federated and Interoperable Architectures

The joint work further highlights that the future European Digital Twin landscape is likely to consist of interoperable Digital Twins operating at different system levels rather than a single centralised model.

From this perspective:

- DSOs develop Digital Twins reflecting distribution system characteristics,
- TSOs operate Digital Twins reflecting transmission system dynamics,
- Interoperability mechanisms enable coordinated modelling and structured information exchange.

Such a federated architecture may strengthen overall system resilience while respecting the distinct responsibilities and operational realities of different system operators.

For the purpose of D3.1, this means that Digital Twin maturity at DSO level must also be evaluated concerning interoperability readiness, data model alignment, and the ability to participate in cross organisational modelling environments.

3 Baseline Analysis of Digital Twin Across European DSOs

3.1 Objective and Analytical Approach

The objective of this section is to provide a foundational assessment of the current state of Digital Twin readiness among European DSOs, in accordance with the mandate of Deliverable D3.1.

The analysis builds upon the exchanges and support needs assessment conducted under Work Package 1, as well as insights gathered through extended outreach activities and expert discussions within DSO Entity's established working structures.

Rather than applying a rigid benchmarking methodology, this baseline assessment follows a structured qualitative approach. It acknowledges the diversity of the European DSO landscape and recognises that Digital Twin development evolves progressively. The objective is not to rank or compare individual operators, but to identify recurring patterns, strengths, structural constraints, and emerging trends that characterise the current state of play.

3.2 Diversity of the European DSO Landscape

European DSOs operate in highly heterogeneous technical, regulatory, and organisational environments. Network topology, degree of electrification, renewable penetration, regulatory incentives, and historical infrastructure development all shape the digitalisation trajectory of individual operators.

Importantly, Digital Twin readiness cannot be inferred from the size of a DSO alone. While larger DSOs may have greater financial capacity to allocate dedicated resources to digital transformation, this does not automatically translate into higher digital maturity. Conversely, several smaller DSOs have demonstrated advanced digital integration as a result of targeted strategic decisions, the initiative of highly engaged individuals or small expert teams.

Size primarily influences the capacity to mobilise resources and sustain long term digital transformation programmes. It does not deterministically define the technological sophistication of digital infrastructure. The baseline assessment therefore avoids categorising Digital Twin readiness strictly by DSO size. Instead, it focuses on capabilities, integration depth, governance structures, and expertise availability.

Nevertheless, it is observed that smaller DSOs often face structural constraints related to limited internal digital expertise and reliance on external service providers. This affects the speed and scope of Digital Twin implementation rather than its conceptual relevance.

3.3 Core Dimensions of Digital Twin Readiness

Based on stakeholder exchanges and expert discussions, Digital Twin readiness among DSOs can be assessed along several interrelated dimensions. These dimensions reflect the functional understanding developed in Section 2 and align with the four outcome areas of the project call.

3.3.1 Data Availability, Integration, and Governance

Digital Twin development is fundamentally dependent on the availability, quality, and interoperability of data. Across Europe, progress in smart meter deployment and substation automation has significantly increased the volume of available data. However, the structured integration of heterogeneous legacy systems remains uneven.

In many DSOs, operational data, planning models, asset databases, and external data sources are still managed in partially separated environments. Data cleansing, harmonisation, and semantic alignment represent ongoing efforts rather than completed transitions. Advanced Digital Twin implementation requires not only data availability but also robust data governance frameworks, which are still maturing in parts of the sector.

3.3.2 Network Modelling and Simulation Capabilities

Most DSOs operate network models for planning purposes. These models are typically used for load flow analysis and reinforcement planning. However, the degree to which planning models are dynamically linked to operational systems varies significantly.

In some cases, planning and operational environments remain institutionally and technically separated. In others, increasing integration enables more frequent model updates and enhanced simulation capabilities. Only a limited number of DSOs currently operate continuously updated models that approach the dynamic characteristics of advanced Digital Twins.

The transition from static planning tools to integrated, continuously updated digital representations remains a key development step.

3.3.3 Observability and Active System Management

With regard to strengthened observability and controllability, substantial progress is visible at the medium voltage level, particularly in networks with high renewable penetration. Sensor deployment, automation technologies, and smart metering infrastructure have expanded situational awareness. We want to mention here that this applies specifically to the grid side of the electricity system. When it comes to the observability of individual HV and MV level installation, further improvements are still needed.

However, observability at low voltage level remains limited in many regions. The integration of distributed energy resources into real-time operational processes is still in very early development across most EU Member States, highly fragmented, and far from being a widespread operational reality. Active system management practices are expanding but often remain confined to pilot implementations or specific network areas.

Additionally, given the system size of the low-voltage grid, it remains unclear whether a concrete business case will emerge to justify fully integrated observability of this grid segment. Digital Twin deployment in this dimension, more realistically, will build upon incremental improvements in instrumentation, automation, and data integration rather than abrupt technological shifts.

3.3.4 Planning, Scenario Analysis, and Flexibility Integration

In the area of infrastructure planning and scenario analysis, DSOs across Europe face increasing complexity driven by electrification, renewable integration, and decentralised flexibility. Traditional deterministic planning approaches are progressively complemented by scenario-based analyses.

However, the integration of flexibility as a structured planning variable and the systematic modelling of demand response remain under development. Digital Twin functionalities such as integrated scenario simulation across operational and planning horizons are emerging but not yet widespread.

Regulatory frameworks also influence the extent to which advanced digital planning tools can be integrated into formal investment processes.

3.3.5 Resilience and Security Considerations

Climate related risks, extreme weather events, and cybersecurity threats have elevated resilience and security to central strategic concerns for DSOs. While contingency planning and asset management frameworks are well established, their integration into dynamic modelling environments varies.

In many cases, resilience considerations are embedded in procedural risk management processes rather than represented through continuously updated digital system models. The systematic use of Digital Twins to simulate stress scenarios, cascading effects, or cyber physical interdependencies remains at an early stage in most contexts.

3.3.6 Interoperability and Cross Organisational Alignment

The federated system of systems perspective described in Section 2 requires interoperability between Digital Twins operated at different system levels. In practice, alignment on common data models and interfaces is still evolving.

While cooperation between DSOs and TSOs is intensifying, practical experience with structured Digital Twin coupling remains limited. Ongoing European initiatives on data spaces and standardisation are expected to play a crucial role in this dimension. It is important to highlight that Digital Twin coupling requires a clear use case that withholds the economic and regulatory framework of the stakeholders involved.

Interoperability readiness therefore represents one of the most critical medium-term enablers for broader Digital Twin deployment.

3.4 Typical Development Patterns

The analysis suggests that Digital Twin development among European DSOs generally follows a progressive trajectory. Initial efforts focus on consolidating data sources and improving observability. Subsequent steps involve integrating planning and operational models, introducing forecasting capabilities, and strengthening data governance.

Advanced stages include dynamic model updating, structured resilience simulations, and participation in interoperable modelling environments. However, these advanced stages remain limited to a very small subset of DSOs, potentially only a handful of outliers rather than an identifiable group throughout Europe.

It is important to emphasise that this progression is not linear nor uniform across Europe. Different DSOs may advance rapidly in one dimension while remaining less developed in others. Digital Twin readiness therefore reflects a multidimensional maturity landscape rather than a single development axis.

3.5 Strengths, Challenges, and Baseline Conclusion Across the European DSO Landscape

Despite heterogeneity, several strengths are consistently observable across the European DSO community. There is a high level of technical expertise in network planning and system operation. The ongoing energy transition has accelerated digitalisation efforts, particularly in areas related to renewable integration and flexibility. Regulatory transparency obligations and European level collaboration platforms have further stimulated data exchange and coordination. These strengths provide a solid foundation for progressive Digital Twin adoption. At the same time, recurring structural challenges affect the pace of Digital Twin deployment. These include fragmented data architectures, limited availability of specialised digital modelling expertise, organisational silos between IT and grid operation functions, and regulatory uncertainty regarding cost recovery for advanced digital investments.

For smaller DSOs in particular, the availability of internal digital expertise often represents a limiting factor. However, as noted earlier, digital excellence is not exclusively correlated with organisational size. Targeted leadership, strategic prioritisation, and collaborative approaches can enable significant progress even within limited resource environments.

The baseline analysis indicates that Digital Twin readiness among European DSOs is advancing steadily but remains heterogeneous across multiple dimensions. Many DSOs are actively strengthening foundational capabilities such as data integration, observability, and modelling, with an increasing focus on delivering demonstrable operational value. However, fully integrated, dynamically updated, interoperable Digital Twin environments remain limited to a very limited number of DSOs, representing isolated exceptions rather than an identifiable group. Digital Twin development across Europe can therefore be characterised as progressive and evolutionary. The identified strengths and structural gaps form the basis for the gap analysis and initial roadmap presented in the subsequent sections of this deliverable, in line with the objectives of Work Package 3.

4 Gap Analysis: Bridging Current Capabilities and Future Digital Twin Requirements

4.1 Purpose and Framing

Building on the baseline assessment in Section 3, this section identifies structural and operational gaps that may slow the broader uptake of Digital Twins at DSO level.

The objective is not to compare DSOs or to define a single target model. Instead, the analysis highlights recurring patterns that limit the transition from existing digitalisation efforts to more integrated and operationally embedded Digital Twin capabilities, in line with the objectives of Deliverable D3.1.

The emphasis is placed on DSO internal readiness and practical implementation challenges. Cross-organisational and federated modelling concepts are acknowledged but are not considered the primary short-term constraint for most DSOs.

4.2 Data Integration and Model Consistency Gap

Across Europe, the availability of grid-related data has improved significantly. However, the structured integration of heterogeneous data sources remains incomplete in many cases. The main gap does not concern the absence of data, but the limited interoperability and consistency between systems. Planning tools, operational platforms, asset databases, and external datasets often coexist without full semantic alignment or automated synchronisation. This fragmentation affects the ability to:

- Maintain continuously updated network models,
- Use operational data systematically in planning simulations,
- Ensure consistency between asset information and operational states.

As a result, many DSOs operate with parallel digital environments rather than a coherent digital representation of the network. Bridging this gap is a prerequisite for any advanced Digital Twin functionality.

4.3 Dynamic Coupling and Real Time Capability Gap

A related but distinct challenge concerns the dynamic integration of operational data streams into modelling environments. While most DSOs possess planning models, these are frequently updated periodically rather than continuously. Automated feedback loops between field measurements and digital models are not yet systematically implemented. This limits the transition from static or semi static models toward dynamic Digital Twin environments capable of supporting near real time decision making. In practice, simulation tools are often used retrospectively for analysis rather than proactively for operational optimisation.

The gap therefore lies not in modelling capability as such, but in the depth of integration between live system data and analytical tools.

4.4 Observability and Low Voltage Visibility Gap

Digital Twin functionality depends heavily on network observability. Medium voltage automation and smart metering deployment have progressed substantially in many Member States. However, low voltage visibility remains uneven.

Since electrification, distributed energy resources, and local flexibility primarily affect low voltage networks, limited instrumentation at this level constrains:

- Accurate congestion identification,
- Reliable flexibility activation,
- Detailed scenario simulation,
- Local resilience assessments.

In many cases, the constraint is infrastructural rather than conceptual. Without sufficient measurement granularity, Digital Twin models cannot fully reflect local system behaviour.

4.5 Integration of Resilience and Security into Digital Modelling

Resilience and security have become central strategic concerns for DSOs. Climate related risks, extreme weather events, and cybersecurity threats are increasingly addressed in risk management frameworks.

However, the systematic integration of these considerations into dynamic modelling environments remains limited. In many organisations, resilience analysis is conducted through procedural assessments rather than through continuously updated simulation environments.

This creates a gap between strategic resilience objectives and operational modelling tools. Digital Twins have the potential to embed resilience scenarios directly into system simulations, but this integration is still emerging in practice.

4.6 Skills, Organisational Alignment, and Resource Constraints

Digital Twin development requires a combination of grid engineering expertise, data analytics capabilities, IT architecture knowledge, and regulatory understanding.

Across Europe, the availability of such interdisciplinary expertise varies considerably. In several DSOs, advanced digital competencies are concentrated in small teams or depend on individual initiative. Organisational separation between IT departments and grid operation functions can further slow integration.

For smaller DSOs, limited internal digital capacity represents a structural constraint. However, as discussed in Section 3, digital maturity is not determined by size alone. Strong leadership, strategic prioritisation, and collaboration can enable significant progress even with limited resources.

The core gap in this dimension concerns the systematic institutionalisation of digital expertise rather than isolated pilot initiatives.

4.7 Regulatory and Investment Alignment

Digital Twin implementation requires sustained investment in digital infrastructure, data governance, and skill development. In some regulatory contexts, cost recovery mechanisms for advanced digital investments remain insufficiently aligned with long-term transformation needs.

This creates uncertainty regarding the economic viability of large-scale Digital Twin deployment. Where regulatory incentives primarily reward short-term cost efficiency, long-term digital transformation may be delayed. Addressing this structural alignment issue is essential to accelerate uptake across the sector.

4.8 Limited Immediate Relevance of Federated Modelling

While interoperability and cross-organisational Digital Twin architectures are strategically relevant for the future evolution of the European electricity system, they do not currently represent the primary constraint for most DSOs.

For the majority of operators, the more pressing challenges lie in internal data integration, model consistency, observability, and organisational readiness. Federated modelling concepts may become more relevant once foundational Digital Twin capabilities are widely established at DSO level. It should be emphasised that federation requires stable, validated, and internally consistent models before any coupling can occur. This is not only a best practice but a strict prerequisite that very few DSOs currently meet. For this reason, federation and system-of-systems approaches are considered a medium- to long-term development perspective rather than an immediate short-term implementation gap.

4.9 Summary of Structural Gaps & Implications for the Roadmap

The analysis identifies several interconnected gaps that affect the practical deployment of Digital Twins at the DSO level:

- Fragmented data integration and limited semantic alignment,
- Insufficient dynamic coupling between operational data and modelling environments,
- Uneven low voltage observability,
- Limited integration of resilience modelling into digital tools,
- Uneven availability of interdisciplinary digital expertise,
- Regulatory uncertainty regarding digital investment recovery.

These gaps do not indicate stagnation. Significant progress is visible across Europe. However, addressing these structural constraints is essential to accelerate Digital Twin uptake in a coordinated and sustainable manner.

The identified gaps suggest that Digital Twin deployment at the DSO level should follow a pragmatic approach. Short-term priorities should focus on strengthening foundational capabilities such as data governance, model integration, and organisational coordination. More advanced functionalities, including structured resilience modelling and interoperability mechanisms, can build upon these foundations. The following section translates these findings into an initial roadmap and implementation support framework, in line with the objectives of Work Package 3.

5 Initial Roadmap and Implementation Support Framework

5.1 Purpose and Scope of the Roadmap

In accordance with the Description of the Action, Deliverable D3.1 shall provide an initial roadmap including achievable short-term steps and an outline of an implementation support framework. The roadmap presented in this section is designed as a structured orientation framework rather than a binding prescription. It recognises the diversity of the European DSO landscape and the multidimensional nature of Digital Twin maturity. The objective is to identify pragmatic steps that strengthen foundational capabilities while creating a scalable pathway toward more advanced Digital Twin functionalities over time.

5.2 Guiding Principles for Digital Twin Deployment at DSO Level

Based on the baseline and gap analysis, several guiding principles emerge for pragmatic Digital Twin development.

A foundational point deserves emphasis before any other: the Digital Twin is the integration, not the tool. Most misunderstandings around Digital Twins stem from treating them as an IT product to be procured. A Digital Twin results from orchestrating processes, data, and models over time, not from acquiring a platform. DSOs should resist the temptation of over-engineered Digital Twin architectures that offer limited operational value. The DSO community has rightly shown caution toward such approaches, and this report supports that instinct.

First, Digital Twin deployment should be use case driven. Investments in digital infrastructure should be anchored in clearly defined operational or planning challenges, such as congestion forecasting, voltage management, renewable integration, or asset lifecycle optimisation.

Second, foundational capabilities take precedence over architectural ambitions. Data integration, model consistency, and internal governance must be strengthened before advanced functionalities can be sustainably implemented.

Third, Digital Twin deployment should be evolutionary. Rather than pursuing disruptive transformation, incremental integration of new capabilities into existing processes is more likely to deliver durable impact.

Fourth, organisational readiness is as important as technological readiness. Digital Twins require interdisciplinary collaboration between grid operation, planning, IT, and management functions.

These principles underpin the staged roadmap described below.

5.3 Short Term Priorities: Strengthening the Foundations

The first phase focuses on enabling conditions that are achievable within a relatively short time horizon and that provide immediate value for DSOs. Priority areas include:

Strengthening Data Governance and Integration

DSOs should aim to improve consistency between operational data, asset databases, and planning models. This may include:

- Establishing clearer data ownership structures,
- Harmonising semantic data models internally,
- Improving data quality management processes,
- Introducing automated synchronisation between key systems where feasible.

Even partial improvements in these areas can significantly enhance modelling reliability.

Improving Model Consistency Across Planning and Operations

Where planning and operational tools are separated, incremental integration should be pursued. This may involve more frequent model updates, structured feedback loops between field data and planning tools, and increased automation of data flows.

The objective is not necessarily to establish real time Digital Twins immediately, but to reduce inconsistencies between digital representations and physical system states.

Targeted Enhancement of Observability

Where low voltage visibility represents a constraint, DSOs may prioritise targeted instrumentation in areas with high renewable penetration or recurrent congestion. Digital Twin deployment should build upon demonstrable operational needs rather than uniform sensor rollouts.

Clarifying Internal Use Cases

DSOs are encouraged to articulate and prioritise specific Digital Twin use cases aligned with their strategic objectives. Clear internal use case definitions improve investment justification and organisational alignment.

These short-term steps are designed to consolidate existing digitalisation efforts rather than introduce entirely new technological layers.

5.4 Medium Term Development Pathways

Once foundational capabilities are strengthened, DSOs may progressively expand Digital Twin functionalities. Medium-term development pathways include:

- Introduction of more advanced scenario simulation tools that integrate flexibility and demand response variables,
- Integration of forecasting models directly into planning and operational workflows,
- Embedding resilience and stress scenario modelling into digital environments,
- Gradual alignment with evolving interoperability standards.

At this stage, Digital Twins begin to move from enhanced digital models toward more dynamic and decision-oriented tools. Federated or cross organisational modelling environments may become relevant for some DSOs at this stage, but only where internal Digital Twin maturity is sufficiently developed.

5.5 Differentiated Pathways Reflecting DSO Diversity

Given the diversity of the European DSO landscape, the roadmap must remain adaptable. For DSOs with advanced digital integration, the priority may lie in enhancing dynamic modelling capabilities and resilience simulations. For DSOs at earlier stages of digital maturity, the focus may be on structured data governance and model consolidation. For smaller DSOs with limited internal digital expertise, collaboration, shared platforms, and knowledge exchange mechanisms may represent more efficient pathways than isolated in-house development. The roadmap therefore does not prescribe a uniform sequence but rather provides a modular orientation framework.

5.6 Implementation Support Framework under DSO4DT

In line with the mandate of Work Package 3, the roadmap is complemented by an implementation support framework to facilitate practical uptake. The DSO4DT project will provide structured support mechanisms, including:

Knowledge Dissemination

Regular webinars and training sessions will present findings from the baseline assessment and highlight good practices emerging across Europe. These sessions aim to translate analytical insights into practical guidance.

Peer Exchange and Community Building

The Digital Twin community established under Task 3.4 will serve as a platform for structured exchange among DSOs, Digital Twin Activities, and other stakeholders. Peer learning can accelerate maturity by sharing practical experiences.

Guidance and Orientation Materials

Non-binding guidance documents may be developed to support DSOs in structuring Digital Twin strategies, defining use cases, and assessing internal readiness.

Integration into the Knowledge Platform

Validated Digital Twin use cases and solutions will be progressively integrated into the upgraded knowledge platform, named DSO-TSO Technopedia, developed in coordination with ENTSO E. This ensures long term visibility and structured dissemination beyond the project duration.

5.7 Action Plan for the Next Twelve Months

In accordance with Deliverable D3.1, the following actions are foreseen for the upcoming year:

- Presentation of the baseline findings through a dedicated webinar,
- Structured feedback collection from DSOs on roadmap prioritisation,
- Development of targeted training sessions focusing on foundational capabilities such as data governance and model integration,
- Continuous coordination with related European initiatives to ensure coherence.

These actions aim to translate the analytical findings of this deliverable into concrete and measurable support activities.

6 Conclusion

This deliverable has established a comprehensive baseline assessment of Digital Twin adoption at the distribution system across Europe. The analysis demonstrates that Digital Twin deployment at DSO level is not a singular technological project but an evolving transformation process that requires sustained effort, coordination, and support.

The structured qualitative approach applied in this assessment has identified recurring patterns, strengths, and structural constraints across the diverse European DSO landscape. By synthesising insights gathered during the first year of stakeholder engagement and expert exchanges, this deliverable provides an analytical reference point that remains neutral, evidence based and aligned with the objectives of the DSO4DT project.

The roadmap presented reflects the current baseline and identified gaps. It prioritises pragmatic, achievable steps while maintaining a long-term perspective on Digital Twin development. The findings will directly inform the concrete and measurable support activities to be delivered through subsequent work packages, ensuring that DSO4DT continues to provide targeted assistance to Digital Twin Activities and European DSOs.

Building upon the foundation established through Deliverable 1.1 and Deliverable 1.2, this baseline assessment enables the project to leverage the knowledge gained through stakeholder exchanges and support the growth of a collaborative community around Digital Twin adoption. The analysis acknowledges the importance of continuous coordination with related European initiatives, research activities, and technical standardisation efforts to ensure coherence and interoperability.

The subsequent iterations of this report under Deliverables D3.2 and D3.3 will build upon the progress observed, track the evolution of Digital Twin deployment across the European DSO landscape, and refine the roadmap accordingly. This iterative approach ensures that the DSO4DT project remains responsive to the changing needs of stakeholders and continues to facilitate the widespread adoption of Digital Twins among distribution system operators.