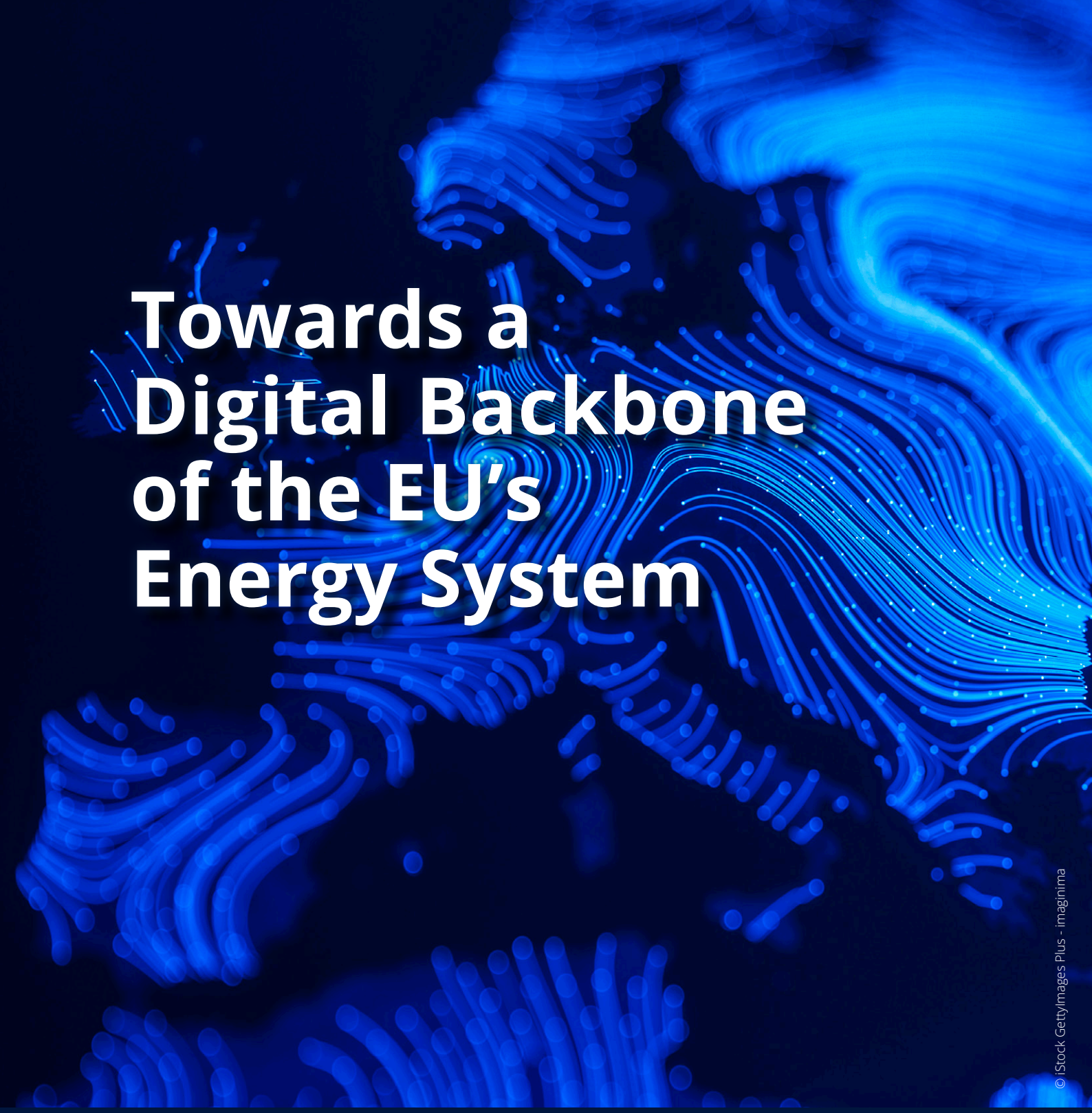
Towards a Digital Backbone of the EU's Energy System



© iStock GettyImages Plus - imaginima

AUTHORS

Razgar Ebrahimy,
Mohsen Banaei,
Konstantin Filonenko

DTU

Lola Alacreu Garcia,
Pablo Bort,
Diego García

etra I+D

Oliver Hoedl,
Georg Hartner

FH OBERÖSTERREICH

Niccolò Fattirolli

olivo ENERGY

The authors of this publication benefited from funding under the European Union's CEF Digital Programme (for the BEGONIA project) and the European Union's Digital Europe Programme (for the ECLIPSE and INSIEME projects). The publication reflects only the views of the authors, and the European Commission is not liable for any consequences stemming from the reuse of this publication.

EDITORIAL NOTE

Artificial intelligence tools were used in the preparation of this report to support drafting, editing, and language refinement. All substantive content, judgments, and conclusions were reviewed and validated by the contributing authors, who remain fully responsible for the final text.

CONTENTS

List of Figures . . . 4

Purpose and Scope of this Report . . . 5

Overview . . . 6

Europe's Vision for Accelerating the Digitalisation of Energy and Mobility . . . 8

Main Barriers to Achieving Automation and System-wide Orchestration . . . 10

A Digital Backbone of the EU's Energy System . . . 12

Core Design Principles for the Digital Backbone of the EU's Energy System . . . 13

1. Distributed by design . . . 13

2. Interoperable and plug-and-play . . . 13

3. Orchestration across system layers . . . 13

4. Secure, role-based access and governance . . . 14

5. AI-enabled and human-governed . . . 14

6. Cross-border and scalable by design . . . 14

Main Building Blocks of the Digital Backbone of the EU's Energy System . . . 15

Building Block 1 A trusted data exchange . . . 15

Building Block 2 Orchestration across operational layers . . . 15

Building Block 3 Edge-to-cloud integration . . . 16

Building Block 4 Trust, cybersecurity, & role-based access . . . 17

Building Block 5 AI-enabled operational intelligence . . . 17

Building Block 6 Consumer, market, and service integration . . . 17

Existing European Building Blocks and Initiatives . . . 18

Priority implementation domains . . . 19

Example 1 Flexibility aggregation and activation to enhance efficiency and grid stability . . . 21

Example 2 Smart and bidirectional charging as a flagship implementation case . . . 22

Example 3 Building-level energy management for energy efficiency, flexibility, and user comfort . . . 23

Example 4 DSO–TSO coordination for enhanced grid observability, congestion management, and system reliability . . . 24

Example 5 Digital platforms for energy communities to support local energy coordination and participation . . . 25

Towards Industrial Implementation . . . 26

Key Barriers to Deployment . . . 29

Conclusions . . . 30

References . . . 31

More Details about the Contributing Projects . . . 33

BEGONIA Project . . . 33

ECLIPSE Digital Project . . . 34

INSIEME Project . . . 35

List of Figures

Figure 1. Europe's vision for accelerating the digitalisation of energy and mobility. 9

Figure 2. Main barriers to achieving automation and orchestration. 11

Figure 3. Core design principles of the Digital Backbone of the EU's Energy System. 14

Figure 4. Main building blocks of the Digital Backbone of the EU's Energy System. 16

Figure 5. Interactions of the Digital Backbone of the EU's Energy System, data space, and involved parties. 20

Figure 6. Overview of the ECLIPSE Digital Open Application (TSO customers). 26

Figure 7. Overview of the ECLIPSE Digital User App version (DSO customers). 27

Figure 8. INSIEME's implementation of Flexible Connection Agreements in Austria and France. 28



Purpose and Scope of this Report

This report has been prepared to support the ongoing efforts to leverage cloud-edge-IoT infrastructure, software and AI tools to serve as a Digital Backbone[1,2] of the EU's energy system and to contribute to the policy reflection led by the European Commission on harnessing the transformative potential of digital technologies and AI as a catalyst for increased vertical integration. It draws on the practical and technical experience of three European initiatives: the BEGONIA[3] project, the INSIEME[4] project, and the ECLIPSE Digital[5] project, which together address operational digital platforms, interoperable data exchange, edge-to-cloud integration, consumer-centric applications, and scalable digital energy services.

Taken together, these initiatives provide a strong basis for examining the Digital Backbone of the EU's energy system as an emerging architectural direction rooted in ongoing European work. The report uses this combined experience to identify the main drivers, building blocks, challenges, and enabling conditions for a more interoperable and scalable digital energy ecosystem in Europe.

The intention is not to present the three projects individually or to promote project-specific results in isolation. Rather, the report draws on their combined experience to support a broader reflection on how Europe can move from fragmented digitalisation towards a more interoperable, trusted, and scalable digital energy ecosystem.

---

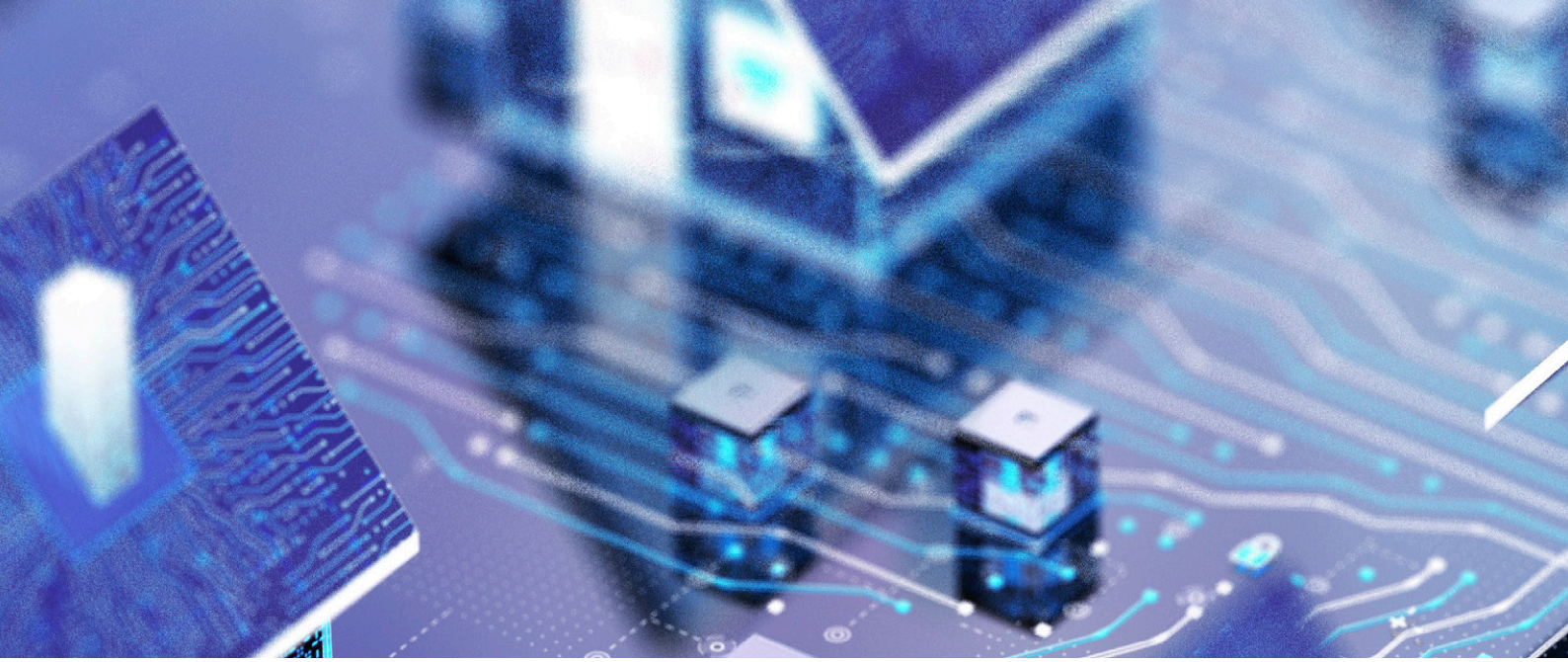
1 EUR-Lex - 52025DC0723 - EN - EUR-Lex

2 The **Digital Backbone of the EU's energy system** is to be understood as the secure and interoperable digital layer that connects energy assets, systems and actors through the cloud-edge-IoT infrastructure, enabling trusted data exchange, AI-enabled optimisation and coordinated action across Europe's increasingly decentralised energy system.

3 The BEGONIA project is an EU-funded Coordination and Support Action (CSA) that contributes to Europe's digital transformation by preparing cross-border Operational Digital Platforms in the energy and transport sectors. The project focuses on identifying use cases, conducting feasibility studies, and preparing modular, scalable, and regulation-aware platform concepts for future implementation.

4 The INSIEME project is a European flagship initiative launched under the EU Digital Europe Programme to help establish the Common European Energy Data Space (CEEDS). Through large-scale collaboration and deployments across Member States, it pilots the core building blocks for secure, interoperable, and high-quality energy data exchange, while connecting existing data-space efforts into a more coherent European infrastructure.

5 The ECLIPSE Digital project is an EU-funded initiative under the Digital Europe Programme that develops, deploys, and demonstrates an open-source Common European Reference Framework (CERF) for consumer-centric energy applications. By promoting secure and efficient data exchange, interoperable interfaces, and AI-enabled energy services, the project supports demand response, consumer engagement, and grid interaction across multiple European pilots.

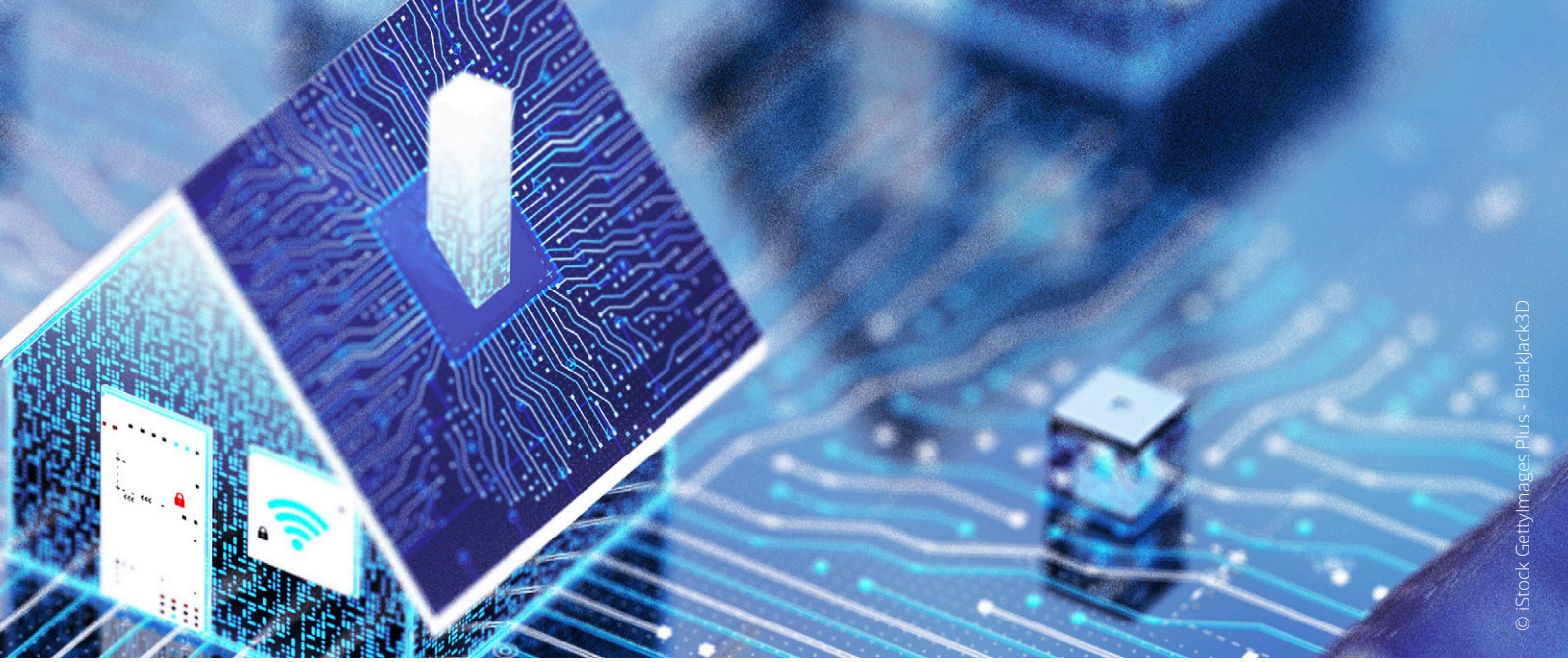


Overview

Europe's energy system is becoming more electrified, more decentralised, and more digital. Renewable generation, distributed energy resources, flexible demand, smart buildings, electric mobility, and active consumers are changing how the system is planned and operated. This transformation creates major opportunities for efficiency, resilience, and new services, but it also increases the need for trusted digital coordination across actors, assets, and sectors.

In this context, the concept of a Digital Backbone of the EU's energy system becomes increasingly relevant. In this report, the Digital Backbone of the EU's energy system is understood as a distributed and interoperable digital layer that helps systems, services, and actors work together more effectively. It is not a single platform, not a new central operator, and not only a data-sharing mechanism. Its role is to support trusted interaction, interoperable processes, and scalable digital services across multiple system levels and jurisdictions.

The need for such a backbone is becoming more immediate. Grid congestion is rising, connection queues are growing, and the integration of large volumes of distributed assets increasingly depends on flexible arrangements, reliable data access, and coordinated digital interaction. At the same time, services such as flexibility aggregation, smart charging, local optimisation, and consumer-centric energy management remain difficult to scale when interfaces, rules, and responsibilities are still fragmented. These conditions affect both system operation and private investment.



Artificial intelligence is also becoming more important in this context. Many energy-system functions already rely on forecasting, optimisation, and control models, but greater digitisation is improving the availability, quality, and governance of data across the system. This creates the conditions for more advanced AI models to support monitoring, automation, orchestration, and operational decision-making in increasingly distributed and dynamic environments.

The European dimension is central to this vision. A Digital Backbone of the EU's energy system should support services that can be reused and adapted across Member States rather than rebuilt from scratch in each national context. Europe already has many of the necessary ingredients, including data spaces, operational digital platforms, flexibility architectures, edge-to-cloud solutions, cybersecurity frameworks, and emerging AI-enabled services. The challenge now is to connect these elements into a more coherent and scalable European direction.

This report argues that Europe should move from fragmented digitalisation towards a more interoperable, trusted, and scalable digital energy ecosystem. The Digital Backbone is presented as an enabling layer that can support this transition by connecting existing efforts, reducing integration complexity, and helping new services and actors participate more effectively across sectors and borders.



Europe's Vision for Accelerating the Digitalisation of Energy and Mobility

Europe is in a decisive phase in which digitalisation and AI are no longer only enablers of the green transition, but core pillars of strategic autonomy, security and industrial competitiveness. It is a moment when major digital and sectoral policy initiatives, such as the Apply AI Strategy and the Strategic Roadmap for Digitalisation and AI in the Energy Sector, are converging to accelerate implementation.

On the digital side, the AI Continent and the Apply AI Strategy identified the energy and mobility sectors as priority domains for the development of advanced AI models, digital twins, and data-driven optimisation, recognising that these efforts must be underpinned by robust cloud-edge-IoT infrastructure, software and AI tools.

In parallel, the Common European Energy and Mobility Data Spaces, developed under the Digital Europe Programme, will begin scaling from blueprint phase into real deployment across Member States.

As part of Europe's broader Tech Sovereignty agenda, the Cloud and AI Development Act will influence how data centres and AI factories operate within the energy system, while the Strategic Roadmap for Digitalisation and AI in the energy sector will help accelerate the sector's digital transformation. In parallel, the Data Union Strategy and the Data Act will shape the wider data governance environment.

Moreover, as cybersecurity remains an essential dimension of digitalisation, appropriate consideration should be given to the sectoral implementation of NIS2, the Cyber Resilience Act and the revised Cybersecurity Act. As more digital devices enter the system, including smart meters, EV chargers and IoT controllers, the energy and mobility communities should work to address supply-chain risks and propose secure-by-design approaches.

This is the context in which a Digital Backbone of the EU's energy system becomes relevant: as an enabling layer for trusted coordination, interoperability, and scalable digital interaction across Europe's energy and mobility ecosystem.

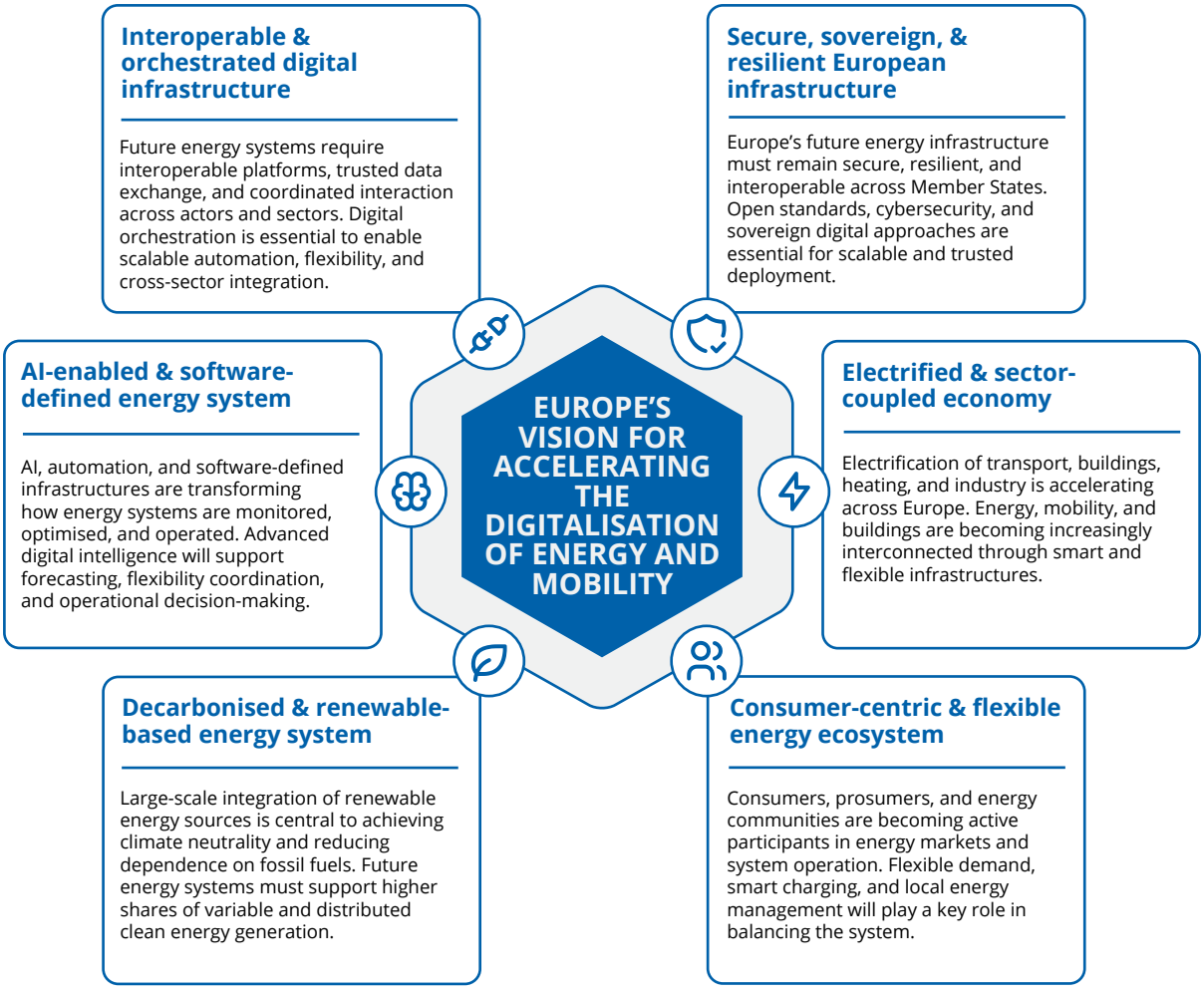


Figure 1. Europe's vision for accelerating the digitalisation of energy and mobility.



Main Barriers to Achieving Automation and System-wide Orchestration

Despite progress on European data spaces, the digital landscape across the energy, mobility, and building sectors remains fragmented. Data spaces provide an important basis for secure and sovereign data sharing, but they do not by themselves solve the wider challenge of interoperability, integration, and operational orchestration across systems and actors.

Different sectors still rely on heterogeneous standards, interfaces, semantic models, and operational procedures. This slows down the scaling of use cases such as demand response, smart charging, vehicle-to-grid services, and energy communities, while increasing dependence on bespoke integration and limiting portability across Member States.

At the same time, Europe's energy system is facing growing digital complexity at the grid edge. The rapid spread of EVs, heat pumps, batteries, rooftop PV, smart appliances, and local energy managers is generating rapidly growing volumes of data, control signals, and coordination requirements. In parallel, energy infrastructure is becoming more software-driven and programmable, which creates new opportunities for flexibility and automation but also expands operational complexity and the cyber-physical attack surface.


© iStock GettyImages Plus - Manoj Madusanka

Governance, trust, and digital sovereignty add a further layer of difficulty. Effective orchestration requires clear rules for data access, responsibilities, consent, liability, and cybersecurity across actors and jurisdictions. It also requires open and interoperable digital foundations that avoid lock-in and support cross-border scalability.

In this context, the challenge is no longer only to exchange data, but to enable systems and actors to interact in a trusted, coordinated, and increasingly automated way.

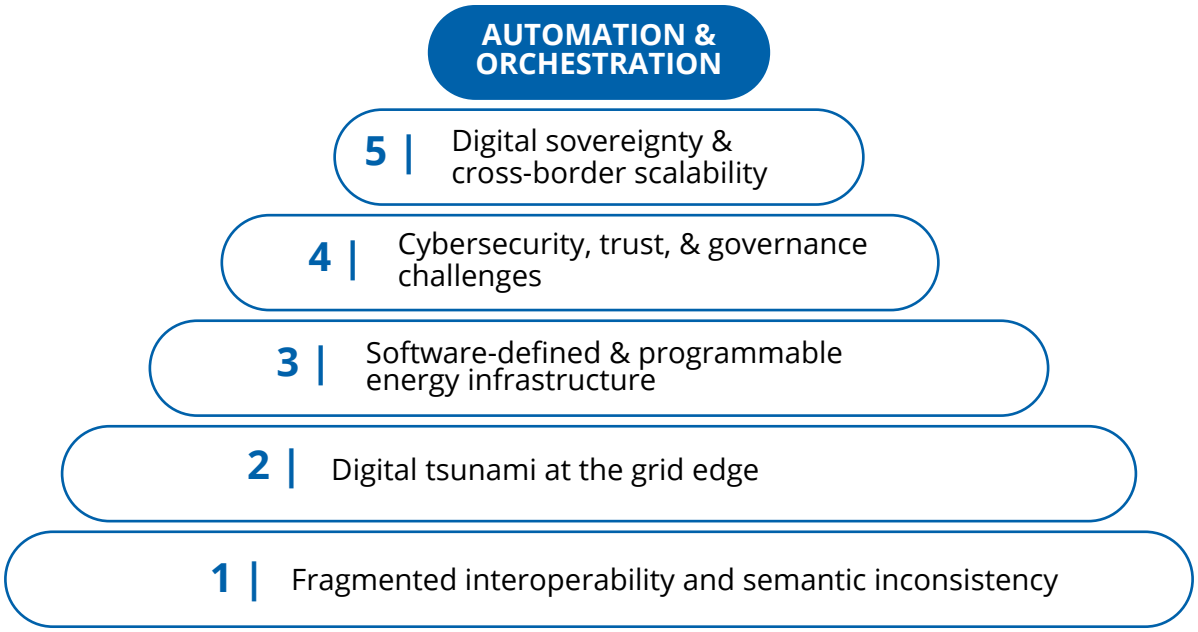


Figure 2. Main barriers to achieving automation and orchestration.



A Digital Backbone of the EU's Energy System

The concept should not be confused with a data space. Data spaces focus primarily on trusted and sovereign data exchange between participants. The Digital Backbone of the EU's energy system addresses a broader challenge: enabling systems, services, and stakeholders to connect, interact, and operate together across organisational and technical boundaries. In this sense, data spaces can be seen as an important component within a wider Digital Backbone of the EU's energy system ecosystem, but they do not by themselves provide the orchestration, semantic alignment, or coordinated automation needed for large-scale system integration.

The Digital Backbone of the EU's energy system is about reducing fragmentation, lowering integration costs, and creating the conditions for reusable digital services, plug-and-play participation, and more effective interaction across the energy ecosystem rather than only exchanging data. This is what makes it relevant for system operators, market actors, service providers, technology companies, and end users alike.

Its key characteristics include a distributed design, interoperable and plug-and-play integration, support for orchestration across system layers, secure and role-based interaction, AI-enabled functions, and cross-border scalability. Together, these characteristics define the Digital Backbone of the EU's energy system as an enabling layer that connects existing digital infrastructures and helps Europe move towards a more interoperable, trusted, and scalable energy system.



Core Design Principles for the Digital Backbone of the EU's Energy System

To operationalise the Digital Backbone of the EU's energy system, a set of core design principles is required. These principles translate the conceptual definition into actionable characteristics that ensure scalability, interoperability, and system-wide coordination.

1. Distributed by design

The Digital Backbone of the EU's energy system should reflect the distributed nature of Europe's energy system, where assets, actors, and decision-making are spread across many technical and organisational layers. It should support coordination without relying on a single central system.

2. Interoperable and plug-and-play

Devices, services, platforms, and actors should be able to connect through shared interfaces, semantics, and trusted access conditions. This reduces bespoke integration and makes innovation easier to scale.

3. Orchestration across system layers

The Digital Backbone of the EU's energy system should support structured interaction across grids, markets, buildings, devices, and services. This is what turns fragmented digital functions into coordinated system behaviour.

4. Secure, role-based access and governance

Data and services should be accessed according to clearly defined roles, responsibilities, and permissions. Strong governance and cybersecurity are essential to ensure trust and controlled interaction.

5. AI-enabled and human-governed

AI can strengthen the Digital Backbone of the EU's energy system by supporting monitoring, automation, orchestration, and decision support. Its use should remain transparent, secure, and subject to human oversight.

6. Cross-border and scalable by design

The Digital Backbone of the EU's energy system should support services that can be reused and adapted across Member States, with local adjustment where needed, rather than rebuilt from scratch in each context.

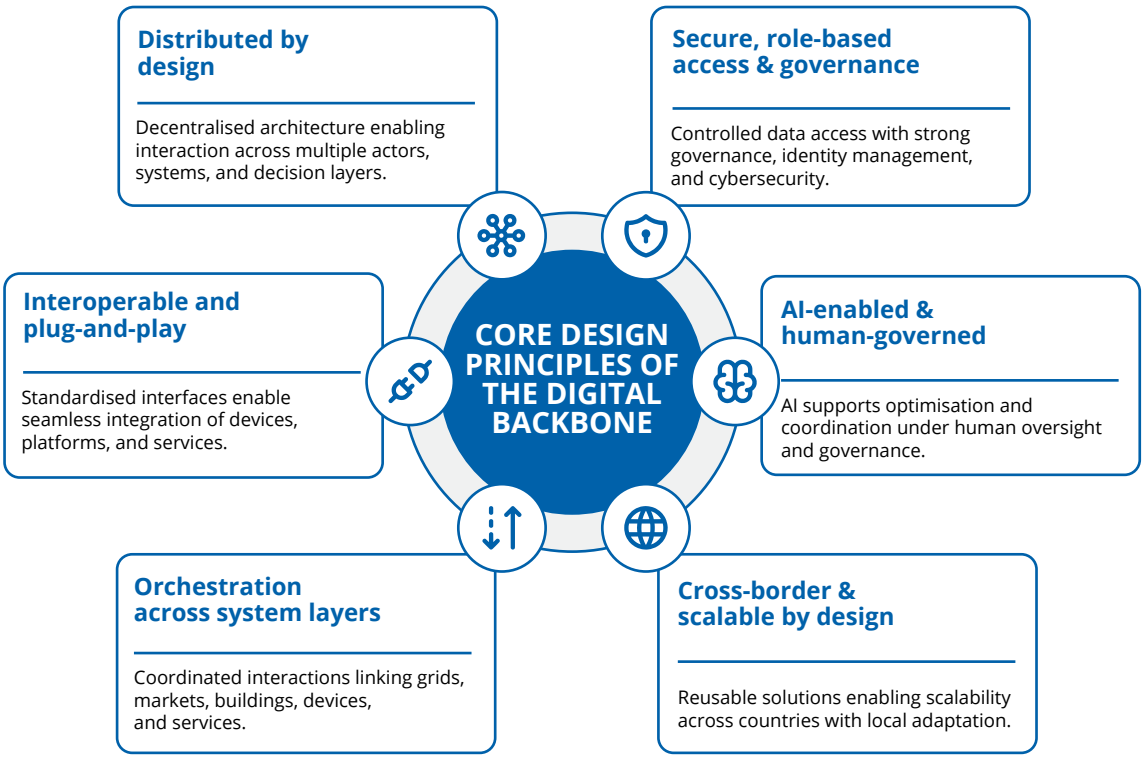


Figure 3. Core design principles of the Digital Backbone of the EU's Energy System.



© iStock GettyImages Plus - everythingpossible

Main Building Blocks of the Digital Backbone of the EU's Energy System

The Digital Backbone of the EU's energy system requires several building blocks that together enable interoperability, orchestration, and scalable service deployment across Europe's energy system.

Building Block 1
A trusted data exchange

A common basis is needed for actors to exchange and use data through shared interfaces, semantics, and governance arrangements rather than through bespoke bilateral integration. Data spaces are important here, and initiatives such as the INSIEME project show how trusted and interoperable exchange can be structured across actors and contexts.

Building Block 2
Orchestration across operational layers

The Digital Backbone of the EU's energy system must connect system-level needs with local assets, services, and decisions. This is where operational digital platforms become important, and where the BEGONIA project helps illustrate how structured interaction between assets, actors, and services can be organised.



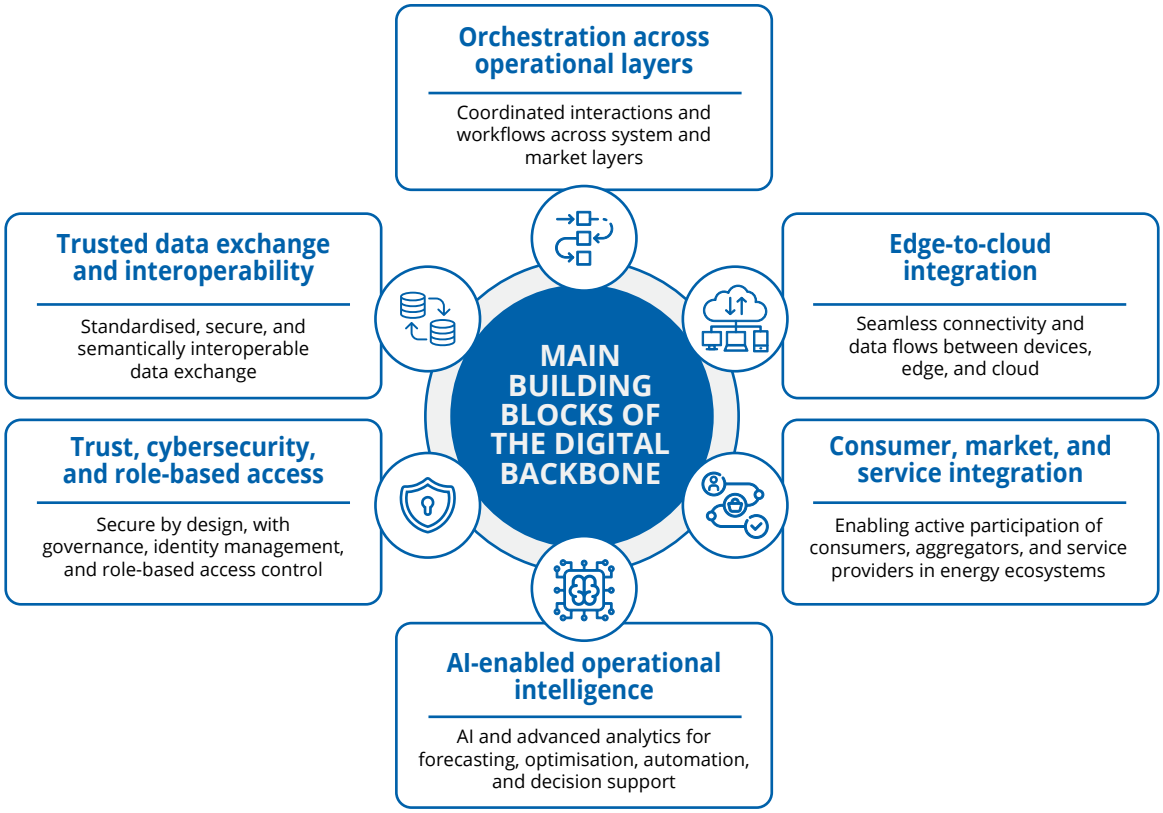


Figure 4. Main building blocks of the Digital Backbone of the EU's Energy System.

Building Block 3
Edge-to-cloud integration

Future energy services depend on effective interaction between local devices, gateways, controllers, and cloud-based applications. The ECLIPSE Digital project is especially relevant here, as it develops interoperable, consumer-centric energy applications and shows how edge-to-cloud coordination can support flexibility, energy efficiency, and grid interaction.



Building Block 4
Trust, cybersecurity, & role-based access

A Digital Backbone of the EU's energy system can only work at scale if access rights, trust conditions, and governance responsibilities are clear. This includes both technical protection and confidence that actors interact under agreed rules and within defined responsibilities.

Building Block 5
AI-enabled operational intelligence

Monitoring, forecasting, orchestration, and decision support are increasingly necessary in distributed and data-rich energy systems. AI strengthens the Digital Backbone of the EU's energy system by making digital interaction more adaptive, more automated, and more operationally useful.

Building Block 6
Consumer, market, and service integration

The Digital Backbone of the EU's energy system should make it easier for consumers, energy communities, market actors, and service providers to participate through interoperable interfaces, reusable service logic, and trusted digital processes. This is essential if new services are to scale across sectors and across borders.



Existing European Building Blocks and Initiatives

Europe does not need to start from zero. Many of the building blocks needed for a Digital Backbone of the EU's energy system already exist in current work on trusted data exchange, flexibility, edge integration, cybersecurity, and AI-enabled energy services. The main task now is to connect these elements into a more coherent and scalable European direction.

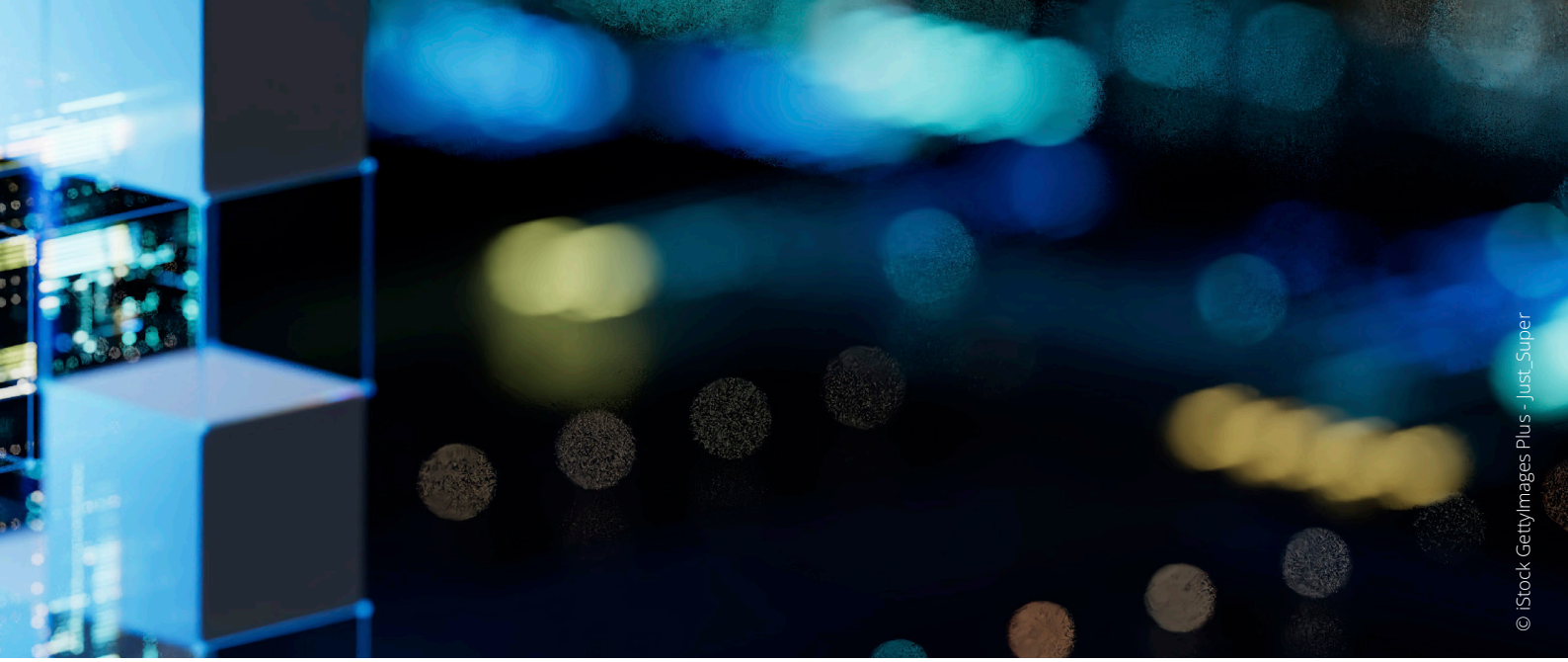
This is also where the three contributing initiatives are relevant. The INSIEME project helps advance trusted and interoperable data exchange through the Common European Energy Data Space. The BEGONIA project contributes to the development of operational digital platforms and cross-border orchestration concepts. The ECLIPSE Digital project helps demonstrate how interoperable, consumer-centric energy applications can be deployed through edge-to-cloud architectures and common reference frameworks.

Taken together, these initiatives show that important parts of a future Digital Backbone of the EU's energy system are already emerging in practice. Their combined value lies in demonstrating how trusted data exchange, orchestration, interoperable services, and user-facing applications can be connected into a more integrated ecosystem.

The next step is to connect these components into concrete implementation pathways that can be adopted by industry, system operators, service providers, and market actors. This means moving from individual technical building blocks towards interoperable, trusted, and sovereign digital services that can be deployed and scaled across different operational environments and Member States.

Projects such as INSIEME, BEGONIA, ECLIPSE Digital, and O-CEI[6] provide practical examples of this transition by developing and testing elements such as trusted data exchange, operational orchestration, edge-to-cloud integration, consumer-facing applications, and interoperability across

6 The O-CEI project is an EU-funded Horizon Europe Innovation Action focused on accelerating the uptake of open and interoperable Cloud-Edge-IoT solutions. Through eight large-scale pilots, it demonstrates cross-domain orchestration and energy-flexibility applications across electricity grids, electromobility, software-defined vehicles, logistics, agriculture, and urban environments.



energy and mobility services. Together, these initiatives show how the Digital Backbone of the EU's energy system can evolve from an architectural concept into a practical implementation framework for Europe's digital energy ecosystem.

Priority implementation domains

Figure 5 provides a high-level overview of use cases that show how the Digital Backbone of the EU's energy system can support interaction across energy, mobility, buildings, and local flexibility ecosystems. Each use case involves a different combination of actors, services, and digital functions, but all depend on the same underlying need: trusted data exchange, interoperable services, and coordinated digital interaction across multiple layers of the system.

The following examples demonstrate how this framework can be applied across different use cases in the energy and mobility sectors. Each use case activates different parts of the Digital Backbone of the EU's energy system and Data Space ecosystem depending on the operational objectives, involved stakeholders, and required digital services. The examples illustrate how interoperable orchestration, trusted data exchange, and coordinated automation can support flexibility management, electromobility, building energy management, DSO-TSO coordination, and consumer and community participation in increasingly interconnected and software-driven energy systems. The coloured indicators included in Figure 5 show which stakeholder groups and ecosystem actors are involved in each example use case, providing an overview of how different parts of the framework are activated across the five scenarios. The implementation domains below are illustrated through complementary experience from BEGONIA, INSIEME, ECLIPSE Digital, and related European initiatives such as O-CEI.

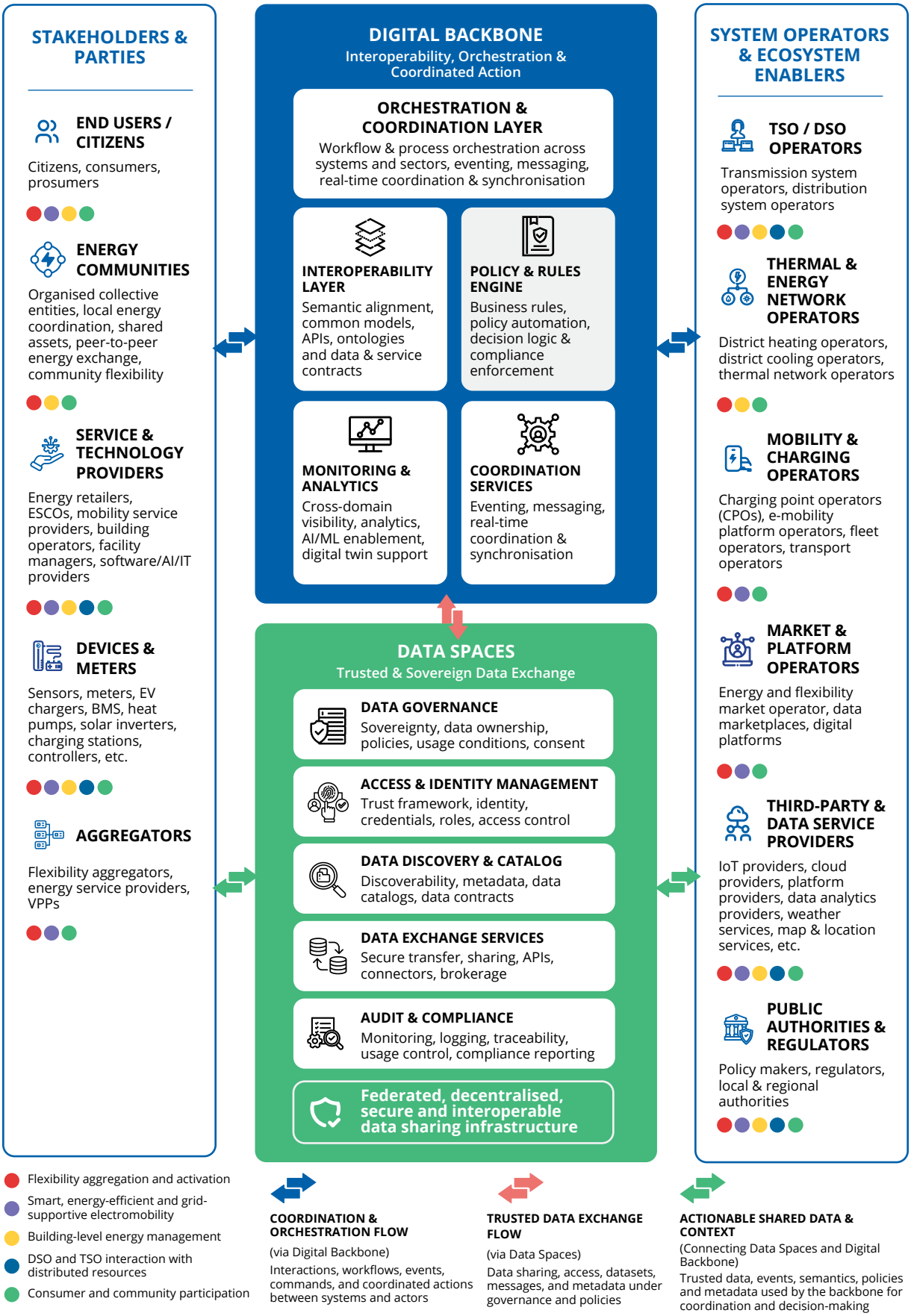


Figure 5. Interactions of the Digital Backbone of the EU's Energy System, data space, and involved parties.

Example 1

Flexibility aggregation and activation to enhance efficiency and grid stability

The rapid growth of distributed generation, electrified demand, storage, EVs, heat pumps, and other flexible assets is increasing the importance of demand-side flexibility across Europe's energy system. These resources can support balancing, congestion management, renewable integration, and more efficient use of existing grid capacity. However, flexibility remains difficult to scale when asset registration, qualification, activation, verification, settlement, and communication between market and system actors rely on different interfaces and procedures.

The Digital Backbone of the EU's energy system can provide a common digital environment through which end users, aggregators, flexibility service providers, market platforms, DSOs, and TSOs interact through trusted and interoperable processes. This can reduce the number of bespoke integrations required to connect distributed assets to flexibility markets and system services and make it easier to reuse the same service logic across different technical environments.

Industrial scale-up will depend particularly on aggregators, energy retailers, flexibility service providers, DSOs, TSOs, market operators, technology platform providers, and appliance and equipment manufacturers. Aggregators and service providers need scalable ways to connect large portfolios of distributed assets, while DSOs and TSOs need reliable interfaces for requesting, activating, and verifying flexibility. Appliance and equipment manufacturers also have an important role by ensuring that devices such as heat pumps, EV chargers, batteries, HVAC systems, and other controllable loads are flexibility-ready and can expose interoperable control and monitoring functions. Market operators and regulators will also be important in ensuring that digital procedures for qualification, bidding, activation, and settlement are sufficiently harmonised to support wider participation.

The social dimension is equally important for scaling flexibility services. End users need to understand how their assets are being used, retain appropriate control over automated actions, and receive a clear and fair benefit from participation. Flexibility services should therefore be designed around transparent consent, user preferences, comfort constraints, and accessible participation mechanisms. Building trust in these services will be essential if flexibility is to move from technically feasible pilots to widespread consumer adoption.

Relevant implementation experience is already emerging through European initiatives working on flexibility, interoperable data exchange, and operational digital platforms, including INSIEME, ECLIPSE Digital, and BEGONIA.

Example 2
Smart and bidirectional charging as a flagship implementation case

Smart and bidirectional charging is a strong implementation case for the Digital Backbone of the EU's energy system because it brings together the energy and mobility sectors around a service that is already moving towards large-scale deployment. Electric cars, trucks, charging infrastructure, mobility platforms, aggregators, grid operators, and energy markets increasingly need to exchange information and coordinate their actions. This becomes particularly important for vehicle-to-grid (V2G), where vehicles can provide flexibility to the power system rather than acting only as electricity consumers.

The Digital Backbone of the EU's energy system can support services such as charging-point discovery and reservation, route optimisation, smart charging, dynamic tariffs, flexibility activation, and V2G. For electric trucks and commercial fleets, these services become even more interconnected because charging decisions depend on route planning, logistics schedules, charging availability, electricity prices, and grid conditions. Cross-border operation adds another layer of complexity, as services should continue to function when vehicles move between Member States without requiring separate technical integrations in every country.

Scaling this implementation domain will require coordinated action across several industries. Vehicle and truck manufacturers need to make vehicles interoperable and capable of supporting smart and bidirectional charging services. Charging point operators (CPOs), charging infrastructure manufacturers, and e-mobility service providers need common interfaces for charging, reservation, authentication, and flexibility services. Fleet and logistics companies can drive adoption at scale, particularly for heavy-duty transport, where coordinated charging can have a significant impact on both operational costs and grid demand. Aggregators, energy retailers, DSOs, TSOs, and market operators need mechanisms that allow vehicle flexibility to participate in energy and flexibility markets. Digital platform and software providers will be important in connecting these different services, while public authorities and regulators need to support interoperability, roaming, market access, and cross-border operation.

The user dimension is also important. Drivers and fleet operators need charging services that are reliable, easy to use, and transparent about price, availability, battery requirements, and the use of vehicles for flexibility. Participation in V2G should respect user preferences and mobility needs, while providing a clear benefit for allowing the vehicle or fleet to support the energy system.

Projects such as BEGONIA, ECLIPSE Digital, INSIEME, and O-CEI address complementary elements of this implementation domain. Together, they provide examples of how interoperable data exchange, operational platforms, consumer-facing services, and cloud-edge-IoT solutions can support the integration of mobility and energy services at European scale.

Example 3

Building-level energy management for energy efficiency, flexibility, and user comfort

Buildings are becoming increasingly active parts of the energy system through heat pumps, rooftop PV, batteries, EV chargers, smart appliances, and building energy management systems. These technologies create opportunities to reduce energy consumption, increase self-consumption, respond to dynamic prices, and provide flexibility to the grid. The challenge is to coordinate these assets and services without adding complexity for building owners, occupants, or facility managers.

The Digital Backbone of the EU's energy system can support this by enabling interoperable interaction between devices, local controllers, energy-management platforms, aggregators, energy service providers, and system operators. Local control can remain close to the building, while relevant information and services are exchanged externally through trusted interfaces and agreed access conditions.

This can reduce the need for bespoke integration and make it easier to add new devices or services over time.

Scaling this implementation domain will require building automation companies, heat-pump and storage manufacturers, appliance manufacturers, energy service companies, aggregators, facility-management providers, and digital platform providers to adopt interoperable interfaces and reusable service models. Device manufacturers also have an important role in ensuring that equipment can communicate its operating status, constraints, and flexibility potential in a standardised way.

The user dimension is particularly important in buildings. Automation and flexibility services need to respect comfort, privacy, and user preferences, while giving occupants a clear understanding of how their devices are being controlled and what benefits they receive. Successful deployment will therefore depend on making these services simple, transparent, and easy to override when needed.

ECLIPSE Digital provides particularly relevant implementation experience in consumer-centric energy applications, interoperable interfaces, and edge-to-cloud integration for buildings and distributed energy assets.

Example 4

DSO–TSO coordination for enhanced grid observability, congestion management, and system reliability

As more generation, storage, EV charging, and flexible demand are connected at distribution level, stronger coordination between DSOs and TSOs becomes increasingly important. System operators need better visibility of distributed resources, clearer information on local constraints, and more efficient ways to coordinate flexibility across voltage levels.

The Digital Backbone of the EU's energy system can support this through interoperable exchange of operational data, forecasts, network constraints, flexibility availability, and system events. Shared semantics and trusted interfaces can improve situational awareness and support coordinated action without requiring the operational systems of DSOs and TSOs to be centralised or replaced.

Scaling this implementation domain will depend mainly on DSOs, TSOs, flexibility providers, grid technology companies, metering and sensor providers, forecasting providers, and operational software vendors. These actors need common digital procedures and interfaces for exchanging relevant information and coordinating flexibility, while regulators and European network bodies will be important in defining where common requirements and implementation rules are needed.

The organisational dimension is also important. DSO–TSO coordination depends on clearly defined responsibilities, trust between actors, and confidence in the quality and timeliness of exchanged information. The Digital Backbone of the EU's energy system should therefore support coordination while preserving operational autonomy and security boundaries.

Relevant implementation experience is already emerging through European initiatives working on system-operator interoperability, flexibility coordination, and trusted data exchange, including INSIEME and ECLIPSE Digital.

Example 5

Digital platforms for energy communities to support local energy coordination and participation

Energy communities are creating new opportunities for citizens, prosumers, municipalities, and local businesses to participate more actively in the energy system. They can support collective self-consumption, local renewable generation, storage, flexibility sharing, and community-based energy services. In practice, however, setting up these platforms often requires complex integration with devices, market actors, billing systems, service providers, and regulatory processes.

The Digital Backbone of the EU's energy system can reduce this complexity by providing reusable interfaces, trusted access mechanisms, common semantics, and digital services that make it easier for community platforms to interact with aggregators, DSOs, retailers, market platforms, and other service providers. This can help local platforms scale without requiring extensive bespoke integration for each new community.

Scaling this implementation domain will require energy community platform providers, municipalities, aggregators, retailers, DSOs, energy service companies, technology vendors, and local authorities to work with interoperable digital processes and reusable service models. Platform providers need solutions that can be replicated across different communities, while municipalities and local actors need services that are easy to deploy and do not require extensive technical expertise.

The social dimension is especially important in this use case. Participation depends on trust, transparency, fair benefit sharing, and clear governance over how community data and assets are used. Digital services should therefore make it easy for participants to understand their role, manage consent and preferences, and see the value they receive from taking part.

Relevant implementation experience is already emerging through European initiatives working on interoperable consumer services, energy sharing, trusted data exchange, and orchestration, including INSIEME, ECLIPSE Digital, and BEGONIA.



Towards Industrial Implementation

Several concrete examples demonstrating the industrial implementation and orchestration of digital energy assets and services are already under way.

Within the ECLIPSE Digital project, the technology provider ETRA has developed a fully operational Energy User application that implements interoperability interfaces, data governance rules, and architecture guidelines based on a Common European Reference Framework for energy-saving applications. The application encourages consumer engagement in energy efficiency by providing eco-friendly tips and suggesting optimal times for energy usage.

In Greece, the application is being demonstrated by the energy and industrial company METLEN and the DSO HEDNO, showing how CERF supports interoperability between energy-sector companies, distribution-grid data and consumer devices. In Cyprus, the TSO (TSOC) is using the application to

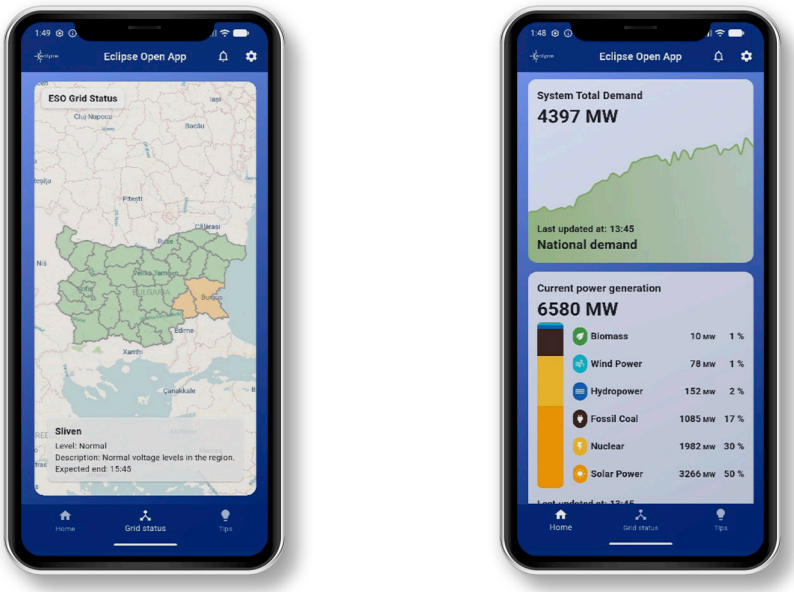


Figure 6. Overview of the ECLIPSE Digital Open Application (TSO customers).



Figure 7. Overview of the ECLIPSE Digital User App version (DSO customers).

enable data exchange between the transmission system and consumer applications. In Bulgaria, the TSO (ESO) is working on connecting the application with the national electricity system and existing digital solutions.

In order to support operation across Member States, the CERF-based applications use the Common European Energy Data Space framework developed by the INSIEME project.

INSIEME's industrial partners are also advancing the implementation of use cases that have the potential to support the Digital Backbone of the EU's energy system.

One particularly mature use case concerns the Flexible Connection Agreements (FCAs), which are being operationalised in Austria, with production deployment planned by June 2027 at the latest.

Netz Niederösterreich[7] and Energienetze Steiermark[8], together with FlexiData and EDA GmbH, are establishing the infrastructure. It builds on the toolset developed by EntArc.eu and Digital4Grids and enables the transition from static to dynamic connection limits. This allows available grid capacity to be reflected in the limits communicated to customer systems.

In France, Enedis and Digital4Grids complement this approach with collective FCAs, where the distribution system operator delegates FCA dispatch across groups of customers to external actors. Adoption of the common FlexiData/EntArc/Digital4Grids model is now also being pursued in Spain.

This is particularly important for vehicle-to-grid integration, where charging and discharging must be coordinated with dynamic import and export limits at the grid connection. The shared model provides the operational link between grid operators, flexibility providers and bidirectional charging systems.

7 **Netz Niederösterreich** GmbH.
8 **Energienetze Steiermark** GmbH.

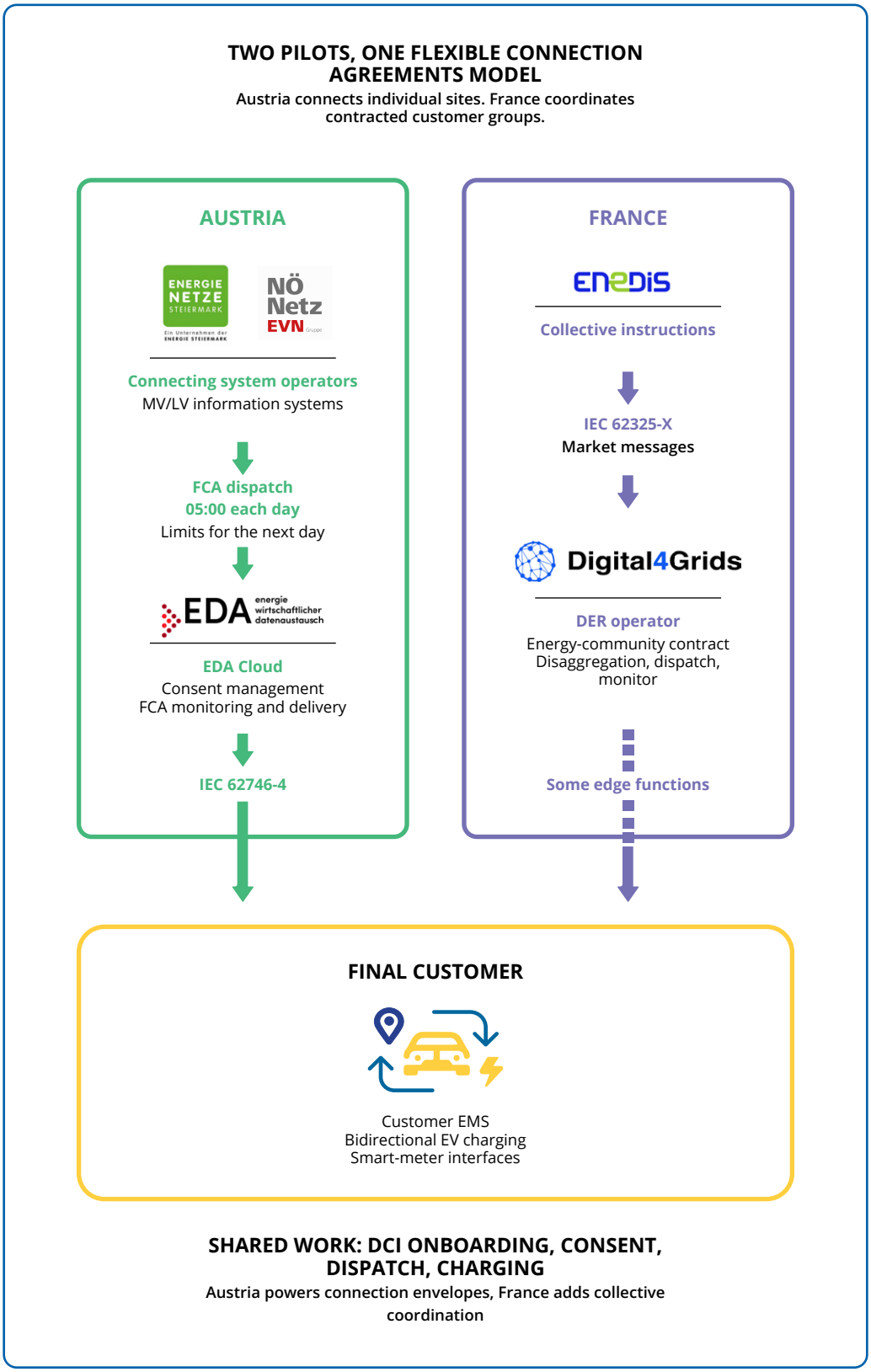


Figure 8. INSIEME's implementation of Flexible Connection Agreements in Austria and France.



Key Barriers to Deployment

Several barriers still stand in the way of a scalable Digital Backbone of the EU's energy system. One of the most persistent is fragmentation in data exchange and interoperability. Many digital functions already exist, but they are too often connected through bespoke interfaces, inconsistent semantics, and project-specific implementations. This makes scaling slower, more expensive, and harder to replicate across contexts.

Another major barrier concerns governance, trust, and role allocation. A Digital Backbone of the EU's energy system depends not only on technical connectivity, but also on clear rules for who can access what, under which conditions, and with which responsibilities. Without this, connectivity does not translate into usable cooperation.

Cybersecurity and resilience are also central. As more devices, platforms, and services become connected, the challenge is no longer only to secure individual components, but to secure interactions across edge devices, cloud systems, and cross-actor exchanges while maintaining operational reliability.

Deployment is further slowed by uneven readiness across actors. Some stakeholders already work with advanced digital services and automation, while others still face limited digital maturity, scarce technical capacity, or legacy system constraints. The Digital Backbone of the EU's energy system therefore has to work across very different starting points rather than assume a uniform digital baseline.

Cross-border portability remains a further barrier. Although many services are technically mature, their deployment still faces obstacles arising from differences in local market structures, regulatory frameworks, access conditions, and implementation practices. This makes scaling across Member States much harder than it should be and limits Europe's ability to deploy digital energy solutions efficiently.

Conclusions

Europe is entering a phase in which digital infrastructure becomes increasingly central to the operation of its energy system. Electrification, distributed flexibility, active consumers, software-defined assets, and cross-sector interaction are creating new opportunities for efficiency, resilience, and innovation, but they also require a stronger digital foundation for trusted and scalable coordination.

In this brochure, the Digital Backbone of the EU's energy system has been presented as an enabling layer for interoperability, trusted interaction, and coordinated digital services across Europe's energy system. Its value lies in making it easier for system operators, market actors, technology providers, communities, and end users to connect and interact through shared interfaces, trusted processes, and reusable digital building blocks.

The importance of the Digital Backbone of the EU's energy system is not only technical. It is also economic and institutional. A more interoperable and plug-and-play system can lower integration costs, support innovation, strengthen flexibility markets, improve the use of grid and system resources, and make it easier for digital energy services to scale across sectors and borders.

Europe already has many of the ingredients needed to move in this direction. The next step is to connect them more coherently with Europe's wider implementation agenda, including the Digitalisation of the Energy System Action Plan, the Common European Energy Data Space, the Apply AI Strategy, the Strategic Roadmap for Digitalisation and AI in the Energy Sector, and initiatives supporting smart electrification and grid modernisation such as AccelerateEU. This should go hand in hand with practical implementation priorities such as demand-side flexibility, vehicle-to-grid integration, cybersecurity, digital sovereignty, and cross-border scalability. The Digital Backbone of the EU's energy system can provide a common digital foundation that helps translate these policy and industrial priorities into interoperable and deployable services across system operators, market actors, technology providers, and end users. It should therefore be seen as a common direction for a more flexible, secure, scalable, and digitally enabled European energy system.

References

[1] Leveraging Twin Transformation | Digital Infrastructures to Advance Decarbonisation at the Nexus of Energy and Mobility, Fraunhofer FIT, study funded by the European Commission, DG CNECT, July 2024.
Accelerating the green transition: the role of digital infrastructures in decarbonising energy and mobility sectors | Shaping Europe's digital future; FIT Press release, 16.07.2024 - Fraunhofer FIT

[2] Novel AI applications in the energy sector - Detailed characteristics building on the emerging energy data space and the development of a digital twin of the energy system, study funded by the European Commission, DG CNECT, June 2025
Artificial intelligence unlocking a smarter, greener energy future | Shaping Europe's digital future

[3] ETIP SNET - Unlocking the Potential of AI and Generative AI in European Smart Grids - A Strategic Position Paper and Guide for Action, December 2025
Unlocking the potential of AI and generative AI in European smart grids - Publications Office of the EU

[4] INSIEME project.
INSIEME - European Energy Data Space

[5] BEGONIA project.
https://www.begonia-project.eu/

[6] ECLIPSE Digital project.
https://eclipse-digital.eu/

[7] AI Continent Action Plan.
EUR-Lex - 52025DC0165 - EN - EUR-Lex

[8] Apply AI Strategy.
EUR-Lex - 52025DC0723 - EN - EUR-Lex

[9] Cloud and AI Development Act.
Proposal for the Cloud and AI Development Act (CADA) | Shaping Europe's digital future

[10] The Data Union Strategy.
EUR-Lex - 52025DC0835 - EN - EUR-Lex

[11] Data Act.
Regulation - EU - 2023/2854 - EN - Data Act - EUR-Lex

[12] Strategic Roadmap for Digitalisation and AI in the energy sector.
EUR-Lex - 52026DC0501 - EN - EUR-Lex

[13] Renewable energy directive.
Directive - EU - 2023/2413 - EN - RED III - EUR-Lex

[14] Alternative Fuels Infrastructure Regulation (AFIR).
Regulation - 2023/1804 - EN - EUR-Lex

[15] ETRA / Grupo ETRA.
https://www.grupoetra.com/

[16] METLEN Energy & Metals.
https://www.metlen.com/

[17] HEDNO (ΔΕΔΔΗΕ).
https://www.deddie.gr/en/

[18] TSOC – Transmission System Operator Cyprus.
https://tsoc.org.cy/

[19] ESO – Electricity System Operator.
https://www.eso.bg/

[20] Netz Niederösterreich GmbH.
https://netz-noe.at/

[21] Energienetze Steiermark GmbH.
https://www.e-netze.at/

[22] EDA Energiewirtschaftlicher Datenaustausch GmbH.
https://www.eda.at/

[23] EntArc.eu.
https://entarc.eu/

[24] Enedis.
https://www.enedis.fr/

More Details about the Contributing Projects

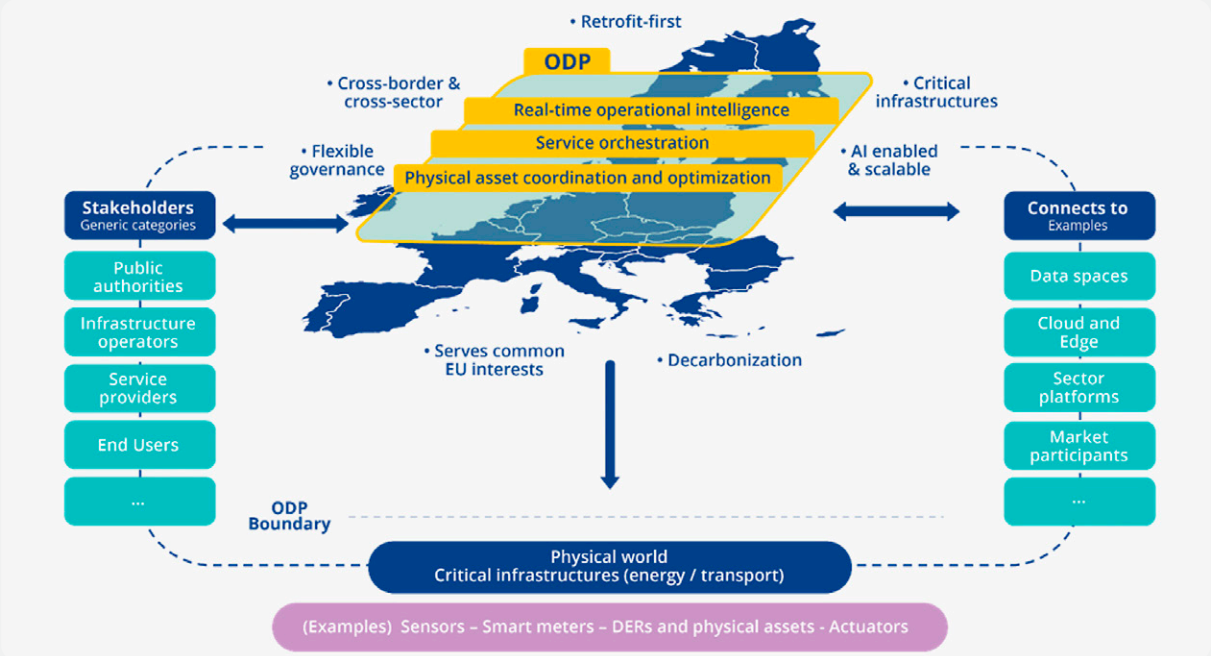
BEGONIA Project

The project developed and validated the concept of the Operational Digital Platform (ODP) and positioned it as a contribution to the broader European discussion on the digital transformation of critical infrastructure.

An ODP, is a purpose-built digital infrastructure that combines physical and virtual ICT resources to connect, coordinate, and operate critical systems. Its defining feature is the ability to go beyond data sharing by enabling real-time operational intelligence, service orchestration, coordinated decision-making, and, where appropriate, interaction with physical assets. ODPs are designed to build on existing European digital ecosystems rather than duplicate them, integrating diverse systems and stakeholders within a common operational framework.

The BEGONIA project has studied, developed, and tested this concept across several use cases, demonstrating its technical and operational feasibility and identifying building blocks that already exist within the European digital ecosystem. At the same time, the project has highlighted structural challenges, including regulatory fragmentation, governance complexity, and the uneven maturity of interoperability frameworks, which will need to be addressed to enable large-scale deployment.

ODPs sit within a broader evolution of the European digital landscape, shaped by developments such as the emerging Digital Backbone concept and advances in Generative and Agentic AI. Rather than competing with these developments, ODPs complement them by translating broader enabling architectures into concrete operational capabilities tailored to specific sectors, use cases, and stakeholder needs.



Source: begonia-project.eu (ODP – the concept)

ECLIPSE Digital Project

The ECLIPSE project emerged in response to significant energy challenges facing the EU and the world. These challenges are exacerbated by volatile energy prices and geopolitical tensions. In this context, there is an urgent need for resilient and sustainable energy solutions.

Digital technologies offer a promising pathway to address these issues, with substantial potential for increasing energy efficiency, reducing costs, and lowering greenhouse gas emissions. Existing applications allow consumers to monitor and manage their energy consumption, fostering more informed and sustainable usage patterns. The working activities and the ECLIPSE partnership have purposely been built upon previous official works addressing the Common European Reference Framework for energy-saving applications (CERF), such as the study by ETRA (ECLIPSE coordinator) "Landscape analysis for energy platforms/consumer applications."

The project is currently deploying and demonstrating the CERF for energy-saving applications across 17 EU countries, involving 10 DSOs and TSOs, 2 retailers, and 8 energy R&D firms. This deployment will enhance consumer engagement, support demand response strategies, and improve grid stability and resilience. The framework will facilitate better management of electricity consumption by responding to grid signals and market conditions and support the integration of distributed energy resources (DERs) and renewables, optimizing grid performance through advanced AI tools.

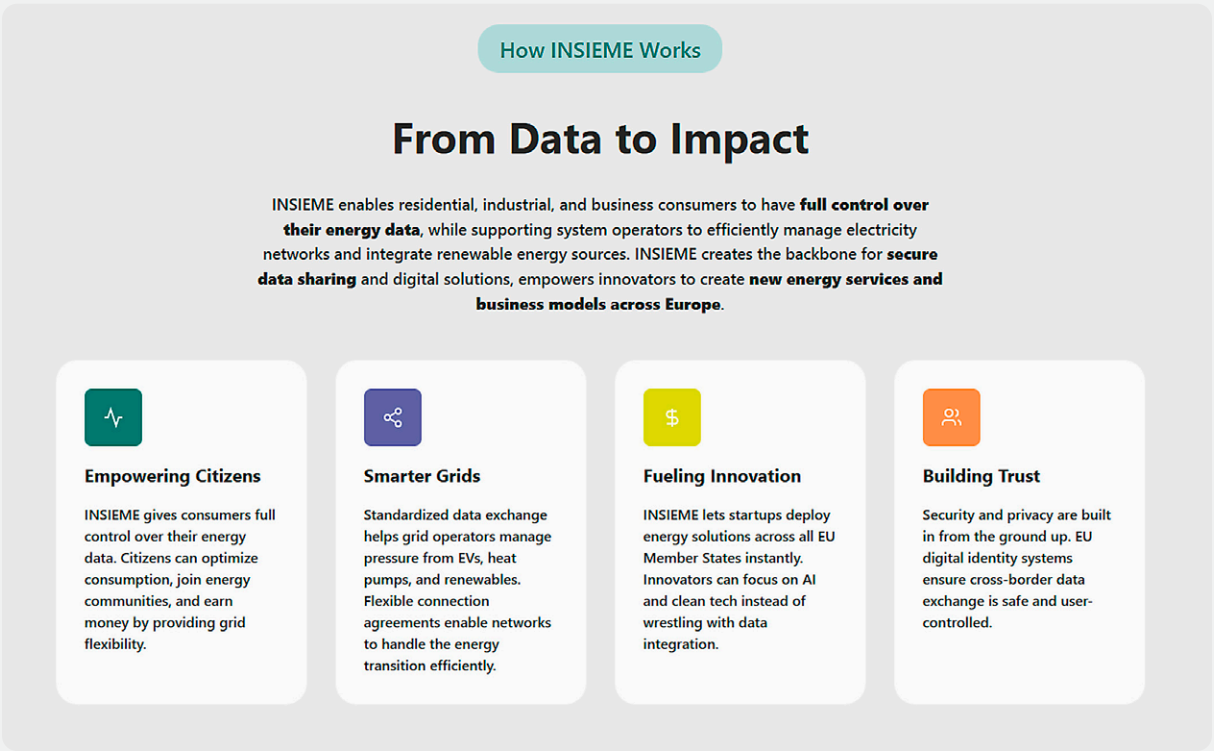


Source: https://eclipse-digital.eu/

INSIEME Project

INSIEME is the European flagship initiative launched under the EU's Digital Europe Programme, in full alignment with key EU digital and sectorial policy frameworks. Building on and aligning with several relevant initiatives (eddie.energy, omega-x.eu, synergies-project.eu, datacellarproject.eu, enershare.eu) and various national data spaces that have been created, INSIEME works to connect and streamline these partial solutions into a Common European Energy Data Space (CEEDS).

INSIEME aims to advance Europe's transition toward fully digitalised, decarbonised, and distributed infrastructures, through large-scale collaboration across the energy and data value chain. With a consortium of more than 50 European partners, INSIEME pilots the remaining building blocks for full operationalisation of the Common European Data Space for Energy, bringing Europe's energy data infrastructure from vision to reality. This is done through 15+ deployments across EU Member States.



Source: INSIEME - European Energy Data Space