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Fraunhofer Cluster of Excellence
"Integrated Energy Systems" CINES

Progress Report on the Digital Transformation of the Energy System

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Management summary

In 2022, the Fraunhofer Cluster of Excellence CINES formulated 14 theses with recommendations for actions by decision makers from industry, business and government to further the digital transformation of the energy system.

The theses reflect on various ways in which digitalization is highly relevant as a key process in transforming the energy system while highlighting the need for overall regulatory and economic conditions conducive to tapping into its full capacity.

To study how the digital transformation of the energy system has evolved and where things are going from here, researchers at Fraunhofer CINES joined forces with partners working in the energy sector to explore the political and regulatory changes occurring in the digital energy sector.

This progress report documents the process as it is unfolding, pointing to advances in the digital transformation of the energy system and discussing areas where action is needed and there is potential for further development. This treatise serves as a guide to furthering the digitalization of the energy sector as a joint effort aimed at bringing about the energy transition.

As the first step, the researchers analyzed relevant changes across five defined topics of focus: data economy, energy systems integration, plant communication, grid operation and planning, and cybersecurity. The results are presented in overview format.

Within the **focus on data economy**, the projects on data spaces in the energy sector show how cross-company data sharing can be implemented in technical terms. In this context, the EU action plan for digitalizing the energy system identifies providing flexibility as a potential driver of the spread of data spaces. This is complemented by the Data Act, which stipulates that various stakeholders' data silos are to be broken down in the medium term. In this way, it is also laying important groundwork for sharing of data between different companies. There is also a need to redouble the efforts put into forging ahead with open data and open source approaches, including in research projects.

Turning our attention to **energy systems integration**, there have been regulatory changes in the heating sector in particular. Together, the German Heat Planning Act (Wärmeplanungsgesetz) and German Building Energy Act (Gebäudeenergiegesetz, GEG) will bring lasting decarbonization in the heating sector, with prominent roles for both decarbonized heating networks and heat pumps. DHC+, the European hub for district heating, has been vocal in its support of a digital transformation to implement heating networks, while section 14a of the German Energy Industry Act (Energiewirtschaftsgesetz, EnWG) will accelerate digitalization in the integration of heat pumps. Even with the new legal bases in place, there is still little controllability in practice with regard to consumption devices, whether in district heating or in terms of heat pumps.

In the field of **plant communication**, the changes brought by the German Act on Restarting the Digitalization of the Energy Transition (Gesetz zum Neustart der Digitalisierung der Energiewende, GNDEW), the redefinition of data relevant to energy, and the definition of an API for the universal ordering process have been especially instrumental in bringing clarity. The accelerated smart meter rollout that this has kicked off is necessary in order to implement controls for grid operation and, going forward, other processes such as direct marketing as well. From the regulatory perspective, the initial focus is on small-scale plants, driven by section 14a EnWG. By contrast, there is still no clarity on the smart meter gateway integration in the existing plant segment, especially in the megawatt range. As far as openly documented plug-and-play-capable interfaces are concerned, EEBus should be viewed as the most relevant candidate right now, but widespread implementation remains to be seen.

Section 14a EnWG is the most important regulatory change in the area of **grid operation and planning**. This law forms the basis for reducing the energy used by consumption devices

smart grid operation. The further evolution of the redispatch process into its current iteration, Redispatch 3.0, means that similar conditions should also be expected on the generation side in the low voltage range. This means regulators are forging ahead with the digital transformation of the lower grid level. In practice, this means building and expanding on internal digitalization capabilities within companies is becoming more and more important for grid operators. This is viewed at times as a dual burden amid the current staffing shortage. The result is that most of the impetus for topics relating to the digital transformation comes from service providers, particularly for smaller and medium-sized grid operators.

Cybersecurity efforts are increasingly widening to include cyber-resilience through a focus on the Detect, Respond, and Recover phases of the NIST Cybersecurity Framework. The EU's NIS2 Directive and the German NIS2 Implementation Act (NIS2-Umsetzungsgesetz) are among the laws and regulations providing a framework for this. In terms of implementation, some companies are already taking important steps toward cyber-resilience, but the majority have not yet considered this topic in their implementation efforts. The lack of trained personnel is an obstacle here as well. Continuing education could ease at least some of the burden in this regard.

In summary, it is possible to identify far-reaching legal and regulatory changes that, in many cases, align with and follow the recommendations for actions set out in our thesis study.

Most of the changes can be viewed as steps in the right direction from the perspectives of both the Fraunhofer Cluster of Excellence CINES and the relevant stakeholders within the energy sector. However, it also became clear from the multifaceted and productive discussions with the aforementioned experts that coherent and integrated objectives for the digitalized energy system in Germany and Europe could afford greater clarity and guidance.

There is a need to craft a shared understanding of guidelines and alignment toward the digital transformation, which will also make it possible to more readily identify potential gaps, areas where action is needed, and positive progress. This will require companies to take action in putting the changes into practice, not merely operating at the individual level but also helping to shape the overall system.

The protectionism that is still observable when it comes to sharing of data and information and disclosure of interfaces is an especially important factor here.

This means a number of aspects are required if the digital transformation of the energy transition is to be brought up to the necessary speed:

- A vision to guide people's actions or specific objectives for where digitalization is to go from here can help provide guidance and foster dialogue among the various stakeholders from government, business and industry, and the research sector.
- Stakeholders from government, business and industry, and the research sector must engage in pathbreaking R&D and implementation projects to create innovative building blocks for efforts such as data space initiatives. Living labs, or regulatory sandboxes, are another possibility here. These projects will ideally have to move beyond the pilot stage in order to have lasting impact.
- Greater emphasis should be placed on communicating and sharing information on progress and successes achieved in groundbreaking projects. Key concepts relating to regulatory changes should be translated for wider communication and made more understandable as well.
- The digital transformation requires a more open approach to data and information so that the systems used by different stakeholders and producers can work together in making the greatest possible contribution to implementing the energy transition.
- In legacy systems, the transformation is associated with path dependencies. There are many digital technologies that need to be put in the right places. Even more specific skills will need to be built here by linking expertise in the digital transformation and energy systems together.
- Digitalization is an integral part of implementing the energy transition, but the cyber-resilience required of critical infrastructure must be present as well. There is an urgent need for investment in this area, along with building of skills for technological solutions to form a single continuous line of defense.
- On the whole, more funds will need to be invested in digitalization and the transformation of the energy system.

1. Introduction

Digital transformation is a key prerequisite for the success of the energy transition. This was the conclusion of the 2022 thesis study on the digital transformation of the energy system, which is referenced above. In the absence of consistent, timely, and efficient digitalization across all sectors, the necessary efficiencies are not unlocked and the system grows disproportionately more complex. Therefore, steps must be taken to advance the digital transformation of the energy system as swiftly as possible, both in Germany and across Europe as a whole.

The thesis study of the digital transformation put forward recommendations for actions to be taken by decision makers in government, business, and industry. These recommendations show where the researchers believe changes will be necessary and meaningful in the next five years. This report analyzes the progress of activities in the area of the digital transformation based on the recommended actions. The purpose of this analysis is twofold. It serves as a basis for highlighting areas of potential for development and challenges while also offering a look at what progress has already been made in terms of the recommended actions and next steps.

The progress report follows the same general structure as the thesis study, which was organized into five key areas: data economy, energy systems integration, plant communication, grid operation and planning, and cybersecurity. For each of these topics of focus, the report reflects on the theses and recommended actions and points out where relevant changes have occurred from the regulatory perspective and among energy sector players. To this end, the authors analyzed the extensive regulatory changes that have taken shape over the last year in particular and set them in the context of the theses. A series of expert discussions was also held to capture views from business and industry, and this input was analyzed.

The report offers a descriptive view of advances in the digital transformation of the energy system and uses it as a basis for identifying necessary measures for further development in the next few years.

2. Data economy

The availability of data unlocks new opportunities for value creation in the course of the digital transformation of the energy system. As a result, building a data economy for the use of data is a highly important factor in the value creation processes within the energy sector. The goal is to establish an open data economy not dominated by individual players. Digital sovereignty, in the sense of control over the use of one's own data — and thus also the relevant share of value creation — should rest with data owners.

In the data strategy for the EU, the European Commission identified energy as one of nine sectors in which data spaces should be developed as data infrastructure. The plan of action for the digital transformation of the energy sector makes clear in concrete terms that providing flexibility for the energy system should be made into a central use case. The first operational energy data spaces are expected to come online starting in 2024.

Extensive strategic activities and fundamental developments are currently taking place at the European and national levels. In technological terms, architectures and software components are being further developed via the initiatives of the Data Spaces Business Alliance (GAIA-X, IDSA, BDVA, and FI-WARE), and architectures are being harmonized. Large-volume data space projects such as CATENA-X are having a particular impact on further advancements in this area. The Data Spaces Support Centre has developed a blueprint to serve as a basis for interoperable data space architectures in the future.

At the same time that this technical development is occurring, European regulatory initiatives are paving the way for a more active data economy. Highlights include the Data Governance Act and Data Act, both of which contain specific points connecting to the use of data spaces.

2.1. Reflection on theses

The thesis study on the digital transformation of the energy system put forward three theses within the data economy focus:

1. **In the future, the value of energy will be dependent on the data associated with it.** [*"Theses for the digital transformation of the energy system,"* Thesis 1].

Natural fluctuations in the generation of electricity from wind and solar sources are increasingly affecting the electricity market. As a result, the value of the energy depends on time-dependent factors and the associated information. At the same time, forecasts of consumption and generation that can be derived from available information and data are growing more important. Data reduce uncertainty, which in turn can increase the value of energy.

2. **Digitally driven value creation networks are the future of the energy system.** [*"Theses for the digital transformation of the energy system,"* Thesis 2].

The digital transformation enables not only process automation, but also changes in value creation across the energy sector. Digital value creation networks are growing more important and raising questions about previous business models.

3. **A sovereign and resilient European energy system requires basic ICT from EU countries** [*"Theses for the digital transformation of the energy system,"* Thesis 3].

The increasing complexity of the energy system requires a high level of digitalization, which in turn creates dependency on the information and communication technologies that form the basis for a sovereign energy system. As a result, preserving knowledge and expertise is of special importance.

This section addresses the extent to which the individual theses have developed over the past year.

Thesis 1: Data increase the value of energy

The thesis study on the digital transformation of the energy system points out the special importance of data in determining the market value of energy. Determining the market value ahead of time is associated with great uncertainty, which can be significantly reduced through data and information (on topics such as the weather situation, grid status, and expected demand, for example). Data can also create added value for energy with regard to proof of origin and the management of generation facilities, power consumers, and storage. Various indicators can be used to monitor trends and necessary actions to ensure that data can in fact provide added value for energy. The increasingly widespread use of dynamic rates for end customers is a relevant measure here. An analysis of rate structures available in recent months with dynamic electricity prices — that is, prices that vary by time — shows that only a small number of suppliers are offering these kinds of rates for now.

Alongside pioneers such as Tibber and aWattar, a handful of other providers operating on the German market offer structures more complex than the peak/off-peak rates that were previously common. Dynamic rates with more time-of-day price levels as envisaged by section 41a EnWG are offered by suppliers such as eprimo, rabot.charge, Voltego, and E.ON. The number of providers is set to increase significantly by January 1, 2025, which is when all electricity providers will be required to offer dynamic rates pursuant to section 41a EnWG,[1] and with the increasing rollout of smart meters, which form the technical basis for charging these kinds of rates.

Electricity supplier	Parent company	Rate plan name	Reference price
aWATTar Deutschland GmbH	tado GmbH	Tarif Hourly	Day-ahead auction (EPEX spot) — hourly product
eprimo GmbH	E.ON SE	eprimoStrom PrimaKlima Dyn	Day-ahead auction (EPEX spot) — hourly product
E.ON Energie Deutschland GmbH	E.ON SE	E.ON ÖkoStrom Dynamisch	Day-ahead auction (EPEX spot) — hourly product
GASAG AG	-	STROM Flex	Day-ahead auction (EPEX spot) — hourly product
MVV Energie AG	-	On request	No public information
RABOT CHARGE GmbH	-	rabot.charge smart	Day-ahead auction (EPEX spot) — hourly product
Stadtwerke Düsseldorf AG	EnBW AG (majority)	Düsselstrom Öko Dynamisch	Day-ahead auction (EPEX spot) — hourly product
Tibber Deutschland GmbH	Tibber AS	Dynamischer Tarif	Day-ahead auction (EPEX spot) — hourly product
Voltego GmbH	-	Voltego Privat	Day-ahead auction (EPEX spot) — hourly product

Table 1: Providers of dynamic electricity rates within the meaning of section 41a EnWG[2]

1 According to the core energy market data register,[1] 1,603 electricity suppliers (not including natural persons) were registered at the end of 2022.

On the whole, it is apparent that greater dynamism has taken hold, and especially for users with electric vehicles or heat pumps, dynamic rates represent a way to significantly increase the value of energy. Going forward, accurate estimates of the proportion of low-voltage customers who are already using dynamic rates will be an interesting way to track this trend further. Plans call for the annual monitoring report published by the German Federal Network Agency to contain a survey of the variable rate structures on offer based on the new version of section 77 of the German Metering Point Operation Act (Messstellenbetriebsgesetz, MsbG), which was adopted in May.

Thesis 2: Digitally operated value creation networks

Multiple digital value creation networks have sprung up on the German energy market. They make relevant contributions to building a data economy and have become an established part of the landscape. Fig. 1 lists some of these platforms. The platforms provide their own data for customers and market partners (OEM platforms), pool data from distributed facilities and data sources (aggregators), organize the procurement of necessary flexibility services through redispatch or provision of control reserves, or perform transparency functions for the general public. Each platform has an operator that is responsible for the platform's operation and for access to the platform. This means collaboration and sharing of data between platform users always takes place through these central operators, which function as intermediaries and gatekeepers.

Transparency and market data platforms	Redispatch platforms	OEM platforms	Aggregators
▪ Smard	▪ Connect+	▪ PV: SMA (SMA Energy Data Services)	▪ Virtual power plant: BayWa r.e., Energy2market, Next Kraftwerke
▪ Core energy market data register	▪ DA/RE	▪ Home energy systems: ▪ Sonnen (sonnenCommunity), Qcells (Q.HOME Cloud), Viessmann (VIShare Energy Community)	▪ Charging management: EnBW mobility+, E.ON Drive, Jedlix, Shell EV Charging Solutions Germany (Shell Recharge), The Mobility House (ChargePilot)
▪ Netztransparenz.de	▪ Equigy	▪ Electric vehicles: telematics infrastructure from OEMs (VW, Mercedes, etc.)	
▪ regelleistung.net	▪ GOFLEX	▪ Grid: Schneider-Electric (EcoStruxure Grid), Siemens (PSS-Sincal)	
▪ MARI			
▪ PICASSO			

Fig. 1: Selected digital platforms in the energy sector

The process of building value creation networks has been a dynamic one in the area of data spaces as well. These spaces are typically developed as part of European or national research projects. Fig. 2 contains an overview of the data spaces relating to energy that have demonstrated a pilot or have even already gone live.

Europäische Projekte

- Live:
  - Green Deal Data Space
- Piloten:
  - Platoon: Predictive Maintenance of Wind Farms
  - Platoon: Smart Grids
  - Wind Energy Generation Data Space
  - ENES Data Space
  - H2-Metaverse (Use Case - Lead-in)

Nationale Projekte

- Live:
  - Catena-X: z.B. CO_2-Fußabdruck
  - Mobility Data Space: z.B. Standorte von Ladesäulen
- Piloten
  - dena-ENDA
  - Energy Data Space (EnDaSpace)

Fig. 2: Data space initiatives at the pilot or live stage according to IDSA Data Space Radar[3]

The software components for the data space infrastructure and the onboarding services have now reached the point of readiness for live operation. There is still a significant need for development with regard to the applications for shared data use, and especially industry-specific applications (see VDMA Construction Plan Study[4]).

Further development work has been undertaken as part of Horizon Europe projects. Five of these projects — Data Cellar, Enershare, Synergies, Omega-X, and EDDIE — are implementing data spaces. They are expected to contribute to the availability of energy-specific applications. Another project at the national level, energy data-X,[5] is to build an energy data space for the energy sector in Germany.

Taking the goals of the EU action plan on digitalizing the energy system[6] as a starting point, the joint European energy data space aims to help provide flexibility in particular. Fig. 3 depicts the core elements of this kind of data space. In addition to the stakeholders involved in providing flexibility, a governance structure is needed for the operation and development of the data space. Identity management and functions for finding the available data are base technical functions.

Fig. 3: Core elements of a European energy data space for provision of flexibility[7]

Thesis 3: Base EU ICT system for sovereign and resilient European energy system

With the increasing digitalization of the energy system and the use of data to optimize and operate power generation facilities, electricity consumers, and storage, dependency on individual digital technologies is rising. At the same time, access to data and information and governance of data economies and data spaces are important foundations for curbing market power and ensuring competitive access for a plurality of players. The goal is a sovereign, resilient energy system. This is why the thesis study on the digital transformation of the energy system identified a base ICT system as an important building block toward reaching the overall aims. Possible indicators to assess the current status are based first on an assessment of which components should be considered to constitute critical base ICT. The focus here is on both hardware (including communication technology for plant control, cloud and backend systems, equipment controllers) and software at the supplier end (such as energy data management systems, billing and customer data management) and among generators and aggregators (including power plant capacity planning, market balancing, and forecasts/predictions).

In terms of reaching the goal of a sovereign and resilient energy system, dependence on individual providers and production countries should be viewed with a critical eye if these providers and countries supply components important to the operation of the energy system. To monitor the current status with an eye to the goal of a sovereign and resilient energy system, critical systems and components should be identified through tools such as surveys of players or experts. It will then be possible to determine the dependencies associated with these components and the extent to which strategies are already in place to scale back critical dependencies. Current legislation on grid and information security acknowledges the importance of supply chains and requires companies to take measures to manage risk in order to ensure the security of the supply chain.[8] Another key measure proposed in the thesis study to enhance resilience and sovereignty is continuous provision of the hardware and software that make up the base ICT system via open source approaches in order to preserve expertise and knowledge in this area. An analysis of the current energy research programs based on the EnArgus database shows that open source and open data approaches do play a role as topics, but thus far have accounted for only a small portion of the overall research program.

Keyword searches for “open source” and “open data” in the EnArgus publicly accessible research database

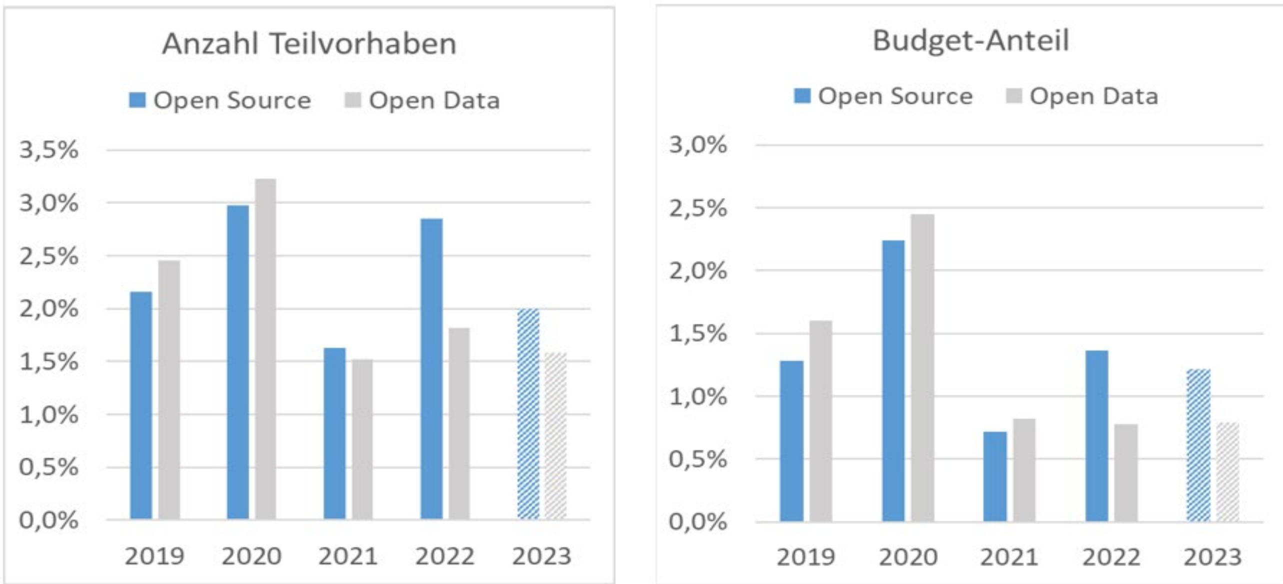


Fig. 4: Subprojects as a proportion of all funded projects relating to open source or open data[9]

2.2. Initial findings

Progress is being made in building and expanding the data economy at the regulatory and technical levels. The Data Act and Renewable Energy Directive (RED III)[10] are expected to open up important additional data usage rights for applications for the energy system and prevent situations in which there are closed-off data silos among only a few major cloud operators. The EU action plan for digitalizing the energy system has led to concrete steps to develop energy data spaces.

Nevertheless, the development and execution of strategy is still at a relatively early stage in Germany. Catena-X, the largest value creation network to date, has gone live in the automotive supply chain. Energy data is already being leveraged to determine carbon footprints in the network.

On the whole, it is difficult to measure the advances made in building a base ICT system in Europe. The use of open source software and open data has been under 2% in the area of energy research funding in recent years based on both the number of projects and funding volume. Stronger support and financing for this concept are needed to ensure that the expertise relating to critical technologies and software remains with multiple providers in Europe and that no critical dependencies arise.

Both in the coming development of governance structures for the common European data space and for additional data spaces, it will be crucial to put common European governance rules in place to enable international players to participate in the market while preventing dependencies and creating a combination between European and national regulations based on the principle of subsidiarity.

In terms of further development, focusing on the energy sector would make sense. The specific topics of focus from the EU action plan as it relates to mobility, smart metering, and aggregators of flexibility can be used as core areas where data spaces can have an especially pronounced positive impact.

Focus on data economy — current CINES activities

1. Recommendations for practical implementation of a common European energy data space for the European Commission in the EU's EnTEC project — https://data.europa.eu/doi/10.2833/354447
2. Building an energy data space based on GAIA-X-compliant components in the context of energy data-X, the latest research project funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) (site in German) — https://www.energydata-x.eu/
3. White paper (text in German) on the use of data spaces for district data — ODH@X — data space for climate-neutral districts — https://opendistricthub.de/odhx-datenraum-fuer-klimaneutrale-quartiere/

3. Energy systems integration

Energy systems integration involves the conversion and storage of energy and materials between the electricity, heating and transportation sectors. Intelligent integration of sectors, whether direct or indirect, can unlock a broad spectrum of synergies and areas with potential for flexibility. Energy systems integration can help

- align energy availability and demand in terms of both timing and geography,
- effectively balance out fluctuations in renewable energy, and
- create financial incentives for flexible behavior that serves the needs of the overall grid, demand-side management, and vehicle-to-grid and power-to-X technologies.

Aside from the technical requirements, such as energy storage and conversion technologies, high levels of digitalization and consistent ICT integration are also necessary in order to tap into these synergies and areas of potential for flexibility. This includes standardized data spaces and high data availability, intelligent measurement systems, fully digitalized and automated processes, as well as digital tools, energy management systems, control systems, and more.

The area of plant communication is essential to energy systems integration. It is addressed in further detail in section 4. This section reflects on current developments in the areas of legislation and guidelines with an influence on energy systems integration.

What developments have there been in these sectors in terms of digital data collection?

The German federal government's 7th Energy Research Programme had already identified alignment toward cross-sector and cross-system issues relating to the energy transition as a guideline, with explicit reference to the digital transformation. Now, in the 8th Energy Research Programme, the topic of digital transformation appears as a core element of the five missions, with a focus on energy systems integration.[11]

Current developments in the heat sector are driven by newly created overall legal frameworks, among other factors. One example is the new version of the German Heating Costs Ordinance (Heizkostenverordnung, HeizkostenV), which took effect at the end of 2021.[12] It establishes rules for the mandatory installation of meters that can be read remotely to determine district heating use. Now that the new version is in effect, all newly installed meters must have remote reading capacity, and existing meters must be upgraded by the end of 2026. The ordinance also requires interoperability with systems from other providers and the possibility of connecting to smart meter gateways under the terms of the German Metering Point Operation Act (Messstellenbetriebsgesetz, MsbG). These requirements are effective starting in 2022. A transitional period lasting until the end of 2031 was established for all previously installed meters.

Section 20 MsbG[13] stipulates that new metering points for gas can only be installed if they can connect securely and reliably to a smart meter gateway (SMGW).

Both of these laws will thus create potential for digital collection of data, with the changes to the Heating Costs Ordinance applying in the heating sector and section 20 MsbG relating to the use of gas. Neither addresses the extent to which actual execution will follow the possibility of connecting to an SMGW.

What developments have there been in the area of energy systems integration at the district level?

The EU's new Renewable Energy Directive (RED III) sets binding sector targets. In addition to raising the overall target for renewable energy as a percentage of gross energy consumption from 42.5% to 45% in 2030, the directive also sets binding sector targets for 2030. For example, an indicative target of 49% was set for renewables as a proportion of heat consumed in the building sector. Renewable energy targets for the transport sector were raised from 32% to 45% in 2030.

Current KfW grants and subsidies such as the funding available for solar power for electric cars are also aimed at continuing to optimize self-generation capacity.

What developments have been observed with regard to the digital transformation of the heating sector?

The German Municipal Heat Planning Act (Wärmeplanungsgesetz)[14] also has the potential to influence the digital transformation of the heating sector. Following the law's planned entry into force as of January 1, 2024, all German municipalities are required to create a heat plan. Large municipalities (population >100,000) are to complete the heat planning process by mid-2026, with smaller towns to follow by mid-2028. The goal is to give both homeowners and tenants some certainty for planning purposes. District heating plays a key role in the transformation. The Municipal Heat Planning Act defines minimum targets for the expansion and decarbonization of district heating networks. By 2045, for example, they are to be supplied exclusively with heat derived from renewable energy and unavoidable waste heat. This will necessarily spur intensified integration of energy systems, which may take forms such as the use of heat pumps or integration with industry to utilize industrial waste heat.

A new subsidy called the German Federal Subsidy for Efficient Heating Networks (Bundesförderung für effiziente Wärmenetze, BEW) was put in place in mid-2022 to support both the development and implementation of suitable transformation paths to the decarbonization of existing heating networks and the planning and construction of new heating networks with high renewable energy percentages. The funding also includes digitalization components in connection with other eligible components. These do not include software costs, however.

The revised version of the German Buildings Energy Act (Gebäudeenergiegesetz, GEG)[15] has introduced binding rules and timelines for shifting from fossil to renewable heating, effective at the same time as the Municipal Heat Planning Act. New heating systems installed in newly developed areas are required to use at least 65% renewable energy as of the start of 2024. The rules for existing buildings and for new infill construction are closely tied to the deadlines for municipal heat planning. In addition to intensified use of district heating, the electrification of heat generation via heat pumps is a core technology at the forefront here.

Neither the Buildings Energy Act nor the Municipal Heat Planning Act directly addresses digital transformation topics. A white paper titled Digitalisation in District Heating and Cooling published by DHC+ (European hub for research & innovation in district heating and cooling) shows why digitalization in the district heating sector is important. It urges immediate action in the digitalization of data at district heating and cooling companies, arguing that it is difficult to identify any other investment with better returns.

The thesis study on the digital transformation of the energy system put forward three theses in the area of energy systems integration:

4. **Without digitalized sector coupling, the costs of transforming energy systems will rise significantly** ["Theses for the digital transformation of the energy system," Thesis 4].

This is because the potential of aspects such as demand-side management, vehicle-to-grid, and power-to-X will only make economic sense through the lens of the digital transformation. With this in mind, smart metering should be realized for all sectors, bringing about a digital transformation across sector lines. And for that to occur, there must be an existing framework for data exchange and open data.

5. **Viable energy business models for digitalized sector coupling at the district level are currently failing due to regulatory hurdles** ["Theses for the digital transformation of the energy system,", Thesis 5].

At the district level, integration of the gas, electricity, heat, and increasingly also mobility sectors is an especially important factor. Use of the potential offered by districts with integration across sectors is currently stymied by regulatory obstacles such as grid fees in amounts that do not reflect actual use of the grid and duplicate charges for decentralized storage. There is no law aimed at leveraging this potential, leaving a very narrow framework within which regional stakeholders, municipal utilities, and city governments can operate. That leaves no incentive for grid-compatible integration of energy systems at the district level.

6. **Efficient decarbonization of the heating sector can only be achieved with digital transformation** ["Theses for the digital transformation of the energy system,", Thesis 6].

Compared to the electricity sector, the heating sector has not experienced much of a digital transformation thus far, although this is the only path to rapid efficiency gains in existing systems. In the medium term, digitalization will form the foundation for the integration of key technologies such as decentralized feed-in, low-temperature networks, and intelligent heat pumps. The digital transformation of the heating sector is the basis for the use of flexibility on the consumption side and preventing the curtailment of generation facilities. It is also a supporting measure for lowering temperatures and incorporating renewable heat into heating networks.

To capture the current status of digitalization in the area of energy systems integration, not only were current regulatory and aid policy developments monitored, but expert discussions were also held to elicit the personal views of players active in the energy supply segment, followed by reflection on the discussion among the experts. The focus here was on reflection concerning the developments seen in recent months and years, projections for the future, and gauging the value added by the digitalization of energy systems.

The results of the surveys were analyzed based on four key performance indicators (KPIs):

1. Digital data availability
We consider digital data availability to mean electronic provision of operation, status, and consumption data. The level of digitalization ranges from no collection of data to data being collected in a proprietary format through to collection of data via standardized interfaces.

2. Digital controllability
When it comes to implementing cross-sector control of plants and systems with as much automation and intelligence as possible, it is desirable to digitalize control specifications and parameters as much as possible. The assessment of digital controllability ranges from plants and systems whose control signals cannot be set digitally at all to those with control specifications in proprietary formats and up to the use of standardized data formats for conveying control signals.

3. Digital value-added services for energy systems integration
Tapping into potential synergies across different sectors requires intelligent use of digitally available data and digitally controllable plants and systems. Digital value-added services provide an incentive for this. One first step here is visualization and/or monitoring of plant or system operation (such as monitoring the EV charging process, operation of heat pumps, and/or consumption and generation of energy, which can be done using methods such as Sankey diagrams). At the next level of development, control is possible using external specifications (such as load management in EVs or the use of lockout periods for heat pumps), and predictive planning/control marks the next step in digital value-added services (examples include EV charging management and controlling heat pumps based on dynamic rates). The maximum degree of digitalization is achieved when value-added services are aimed at cross-sector and/or cross-system control (examples include (bidirectional) charging management based on generation and consumption forecasts, pooling of heat pumps, and optimization of the use of energy at the district level).

4. Funding and incentive systems
We also wanted to know how funding and incentives can contribute to a successful digital transformation in the area of energy systems integration. To what extent are the available funding options already being utilized? What obstacles hinder the use of funding programs at present, and what might a targeted and efficient funding and incentive landscape look like in the future?

Digital data availability:
Nearly all survey respondents indicated that end-to-end collection of measurement data is already taking place in the area of feed-in to their heating networks. This means that data are already largely available on the feed-in side.

Digital data availability on the consumer side is another story. Of course, all consumers are equipped with some kind of meters, which are required in order to carry out the core function of billing for the heat consumed. Responses regarding the proportion of meters that can be read remotely vary widely, ranging from 0% to 90%. The results reflect the fact that digital metering on the consumer side has sharply gathered pace in recent years, going beyond the statutory regulations on remote readability via drive by or walk by. LoRaWAN radio technology has given a significant boost to the digitalization of consumption metering. GSM and existing fiber optic connections are also used to transmit measurements, however.

In addition to the collection of measurements on the feed-in and consumer sides, the pros and cons of additional measurement points within the network were also discussed. During the roundtable discussion, the experts weighed whether these kinds of additional measurement points — which can be laborious and costly to put in place — might be replaced at least in part by highly effective simulation models of the district heating network.

On the topic of standardization of the data available digitally, it was determined that survey respondents currently use cloud systems to store their data. In the current operating environment, these systems seem simpler and more flexible to handle than connecting via a smart meter gateway (SMGW). The experts view the time, effort, and expense involved in providing data through an SMGW and the associated restrictions as outweighing any potential benefit at this time.

Digital controllability:
The picture that emerges for digital controllability is similar to the situation with digital data availability. While across-the-board controllability is a prerequisite for stable operation of heating networks on the feed-in side, there is practically no possibility of intervening for control purposes on the consumer side thus far.

The respondents who participated in the expert discussion did not believe controllability on the consumption side was the focus of development efforts to date, although there was a definite awareness of the potential involved.

Digital value-added services for energy systems integration:
Survey participants were asked how the data collected are currently used. Almost all of the respondents currently use the data for billing purposes, followed by monitoring of grid status and control. Use of the data collected to prepare demand forecasts and plan for the utilization of generation capacity on that basis is not a very widespread practice at this time, even though this point was identified in the expert discussions as having the greatest potential in the core business of supplying district heating. However, there is still a great deal of untapped potential in this area, owing to sources of error, technical issues, and inconsistent data.

Integrating new and digital components into a heating network operator's existing and established overall system represents a further challenge. However, this is the basis for boosting efficiency through more-dynamic operation of the generation facilities and the heating network itself and for the use of flexibility on the consumer side.

Another value-added service that can be tapped into through a higher level of digitalization is reporting for customers. Switching from annual to monthly consumption data is only the first step in this.

Further value that can be added through the digitalization of heat consumption data was identified on both the consumer and housing sector sides. The newly created data basis constitutes an important building block for energy management at the local level, such as in districts or smart cities.

Funding and incentive systems:
Only a few respondents indicated that they had previously utilized funding options. With this in mind, participants in the expert discussions were asked about which funding options were familiar to them. The European Regional Development Fund (ERDF) funding programs and the EnEff:Wärme initiative were mentioned. Neither specializes in the digital transformation. When asked why much of the support available for digitalization in the heating sector is currently going unused, respondents pointed above all to the time, effort, and expense involved in applying for and conducting funding and research projects. Research projects also have to follow a very rigid schedule, making them difficult or even impossible to incorporate into the day-to-day business. Less complexity and greater flexibility in funding processes would be desirable.

Energy systems integration

3.1. Initial findings

Many companies are making good progress in their evolution into data-based organizations and have embraced this as a goal. Strategies are in place for the profitable use of data. It is important to include topics relating to digitalization in the considerations surrounding the impending transition to a green heat supply right from the start. Further work to improve the data basis is needed in order to achieve these aims; the additional data collected must be incorporated within organizations in a useful and productive way, and the relevant stakeholders must be empowered to work with the data.

The mood among experts is largely congruent with the theses laid out in the Fraunhofer thesis study and ties in with the actions recommended in the study. The survey results show that the theses are still valid in the area of energy systems integration. They also bolster the following recommendations for actions to take:

- The focus should be on funding and research projects that consider all sectors.
- Enhancing data quality and quantity is already a focus within the heating sector, and efforts in this regard are moving in a positive direction. When data are collected, for example as part of municipal heat planning, there should be a focus on also making the data available for additional purposes and stakeholders.
- Training and education opportunities should be created to empower all relevant stakeholders to work with the new and digitally available data.
- The potential of value-added services at the district level that are made possible by the digital transformation has been recognized, and goals have been set for decarbonization in the building segment. Current funding is still aimed to a great extent at optimizing in-house consumption in individual buildings. To incentivize the use of flexibility potential within a district, the regulatory obstacles that currently exist on points such as grid fees will need to be eliminated and suitable funding programs created.
- Efforts to support innovation and investment in intelligent heating concepts should be not only ramped up but also streamlined and made more flexible.
- Aspects relating to digitalization are too much of a background issue in current funding programs, so they go largely unnoticed. It would be beneficial to link efficiency programs with smart solutions.

The projects and activities listed below are prime examples of the topics covered by Fraunhofer energy research in the area of energy systems integration. In this way, Fraunhofer makes a significant contribution as a key player and source of innovation in energy research with a high degree of alignment with industry requirements.

Focus on energy systems integration — current CINES activities

1. Decarbonization of industry through transformation of secondary processes that integrate energy systems in the ZORRO II research project — https://zorro-thueringen.de/en
2. AGENT4heat: use of flexibility potential in district heating networks for cross-sector energy system planning in the research project — https://www.enargus.de/pub/bscw.cgi/?op=enargus.eps2&q=%2201258223/1%22&v=10&id=31410868
3. Charging services for residential districts using locally generated solar energy in e-communities within the SharedAC research project — https://sharedac.de/
4. Demonstration of the benefits of return feed-capable vehicle fleets for companies as part of the BiFlex-Industrie research project

4. Plant communication

Plant communication encompasses all of the communication pathways within the energy system that are used to monitor and control energy plants and systems, such as renewable generators and controllable loads, from the grid and market perspective. The core requirements relating to plant communication include ensuring a reliable communication pathway and coping with growing data volumes while keeping latency as low as possible and ensuring maximum cost efficiency. The latter is an especially important factor with regard to smaller, decentralized energy plants and systems.

Plant communication in Germany is currently undergoing fundamental change. Plans call for future plant communication for decentralized energy plants and systems, from end consumers to individual large-scale plants, to take place primarily using smart metering systems.[2] The central tool for this is a locally installed smart meter gateway (SMGW), which is to be used as a key security anchor for connecting the system. The discussions below explore the extent to which this "new world" will be adopted in practice. As an introduction to the topic, the next subsection provides an overview of relevant recent regulatory developments.

4.1. Overall regulatory environment

During the reporting period — the past year — the following new provisions and draft versions of legislation in particular have an influence on the area of plant communication.

Act to Restart the Digitalization of the Energy Transition (Gesetz zum Neustart der Digitalisierung der Energiewende, GNDEW)

The Act to Restart the Digitalization of the Energy Transition (GNDEW) of May 22, 2023,[16] and the associated adjustments to the Energy Industry Act (EnWG), Metering Point Operation Act (MsbG), and Renewable Energy Sources Act (EEG) are aimed at accelerating the rollout of smart metering systems and/or smart meter gateways.

The centerpiece of these acceleration efforts is the "agile rollout," which can begin effective immediately with equipment that is already certified. In the low voltage range, the metering point operator can start the rollout right away if there are measuring points at metering points with annual consumption of up to 100,000 kWh or measuring points with metering points with installed power of up to 25 kW and the following functions are added through software updates starting no later than in 2025:

- Logging of measurements from metering devices
- Remote control capability for the connected end consumers and generation facilities
- Transmission of master data from connected devices and systems

2 A smart metering system is essentially made up of a digital electricity meter, which is the modern metering device (mME), and the connected communication platform, the smart meter gateway (SMGW). The smart metering system infrastructure includes other key system components, such as communication adapters (examples include control boxes) and backend systems operated by the gateway administrator and/or passive or active external market players that access the SMGW and the underlying components (meter, control boxes, etc.) locally.

Beyond that, specific equipment obligations are established for the "normally responsible" metering point operators (95% of all metering points to be equipped by the end of 2030 or 2033, as the case may be), which also establishes a basis in law for the rollout roadmap.[17]

Fig. 5 shows the statutory rollout roadmap for these operators.

In addition, de-bureaucratization is taking place by eliminating the "three-manufacturer rule" in the case of SMGWs, which required certification for three independent manufacturers at each development step. As a result, even one certified manufacturer is now enough to roll out new functions in the field.

The distribution of costs is being adjusted as well. Metering charges are being capped, for example, with grid operators being asked to bear a larger share of costs. Starting in 2024, private households and small-scale generators can expect to pay a maximum of €20 per year (gross) for a smart metering system, the current cost limit for a modern metering device. This is expected to enhance acceptance among end customers.

In return, grid operators are receiving expanded data communication rights (such as exact grid status data down to 15-minute increments and daily transmission of the data to the grid operator — by default without any charges for the metering point operator). There is also now a stronger possibility of installing the SMGW as a secure and reliable communication platform at the grid connection point (controllable grid connection), with interfaces that can then pool multiple consumers together.

Beyond that, the GNDEW offers the explicit possibility of 1:n metering, meaning connecting multiple metering devices to a single SMGW, which may simplify and accelerate the rollout in multi-family buildings, for example. On the whole, this should mean it is possible to install fewer SMGWs.

In terms of standardization, it has been clarified that the German Federal Office for Information Security (BSI) is focusing on SMGW standardization, and that this is taking place on behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK). The BSI is urged to involve further stakeholders (such as associations or funded research projects) at an early stage and to support standardization projects (standardization partnerships). There has been no change in the BSI's existing responsibility for cybersecurity with regard to the SMGWs, however.

Obstacles involving the secure supply chain have also been eliminated; for example, SMGWs can now be transported via a simplified procedure involving conventional courier, express, or parcel delivery. Simplified processes must be drafted by the end of 2023 under the auspices of the BSI.

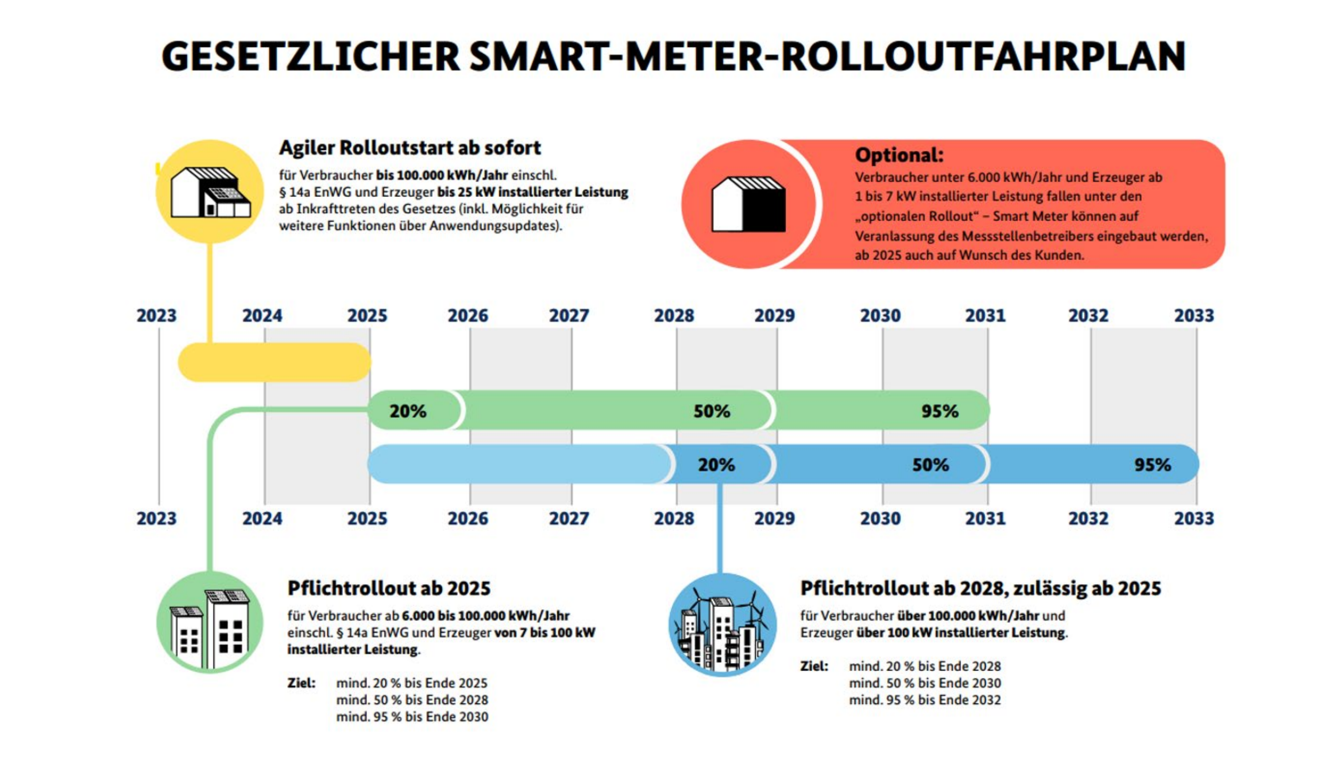


Fig. 5: Rollout planning according to the new GNDEW[18]

Definition of "data relevant to the energy sector"

In the Act to Restart the Digitalization of the Energy Transition (GNDEW), the legislature defined data relevant to the energy sector (ERD) as "standard and additional services as defined in section 34 of the Metering Point Operation Act (MsbG) that are relevant for calculation, accounting, or grid purposes" and presented an exhaustive list of the relevant measurement and control data. These data encompass services pursuant to sections 13a, 14a, and 14c of the Energy Industry Act (EnWG), along with direct marketing under the Renewable Energy Sources Act (EEG) and Cogeneration

In its position paper dated July 13, 2023,[19] the German Federal Network Agency specifies that if the relevant measurement, control, and communication technology is connected to an SMGW, those data can only be transferred using the SMGW's SM-PKI secured wide area network (WAN). By contrast, operating data can also be transmitted via further WAN-capable communication networks if there is no other obligation to use an SMGW.

Simplifications in calibration regulations for smart meter gateways

This reporting period also brought an adjustment to the German Measurement and Verification Act (Mess- und Eichgesetz, MessEG) by way of voting in the German Federal Council (draft of a third act amending the MessEG). Highlights include unlimited validity of calibration (up from eight years) and simplified update processes. This means it is no longer necessary to replace SMGWs after eight years for reasons due to calibration regulations, and there is also no need for the time-consuming and laborious process of obtaining authorization to update firmware via the state calibration authorities. If there is a certificate of conformity for the update, gateway administrators can perform the update themselves. Afterward, a successful self-test of the SMGW by the gateway administrator is required. In addition, plans call for eliminating the advance approval procedure and spot checks.

Introduction of a universal ordering process with API Web service

The German Federal Network Agency (BNetzA) made its determination on the procedure for handling control actions via iMSys (universal ordering process) on November 21, 2022 (BK6-22-128).[20] In response, the German Association of Energy and Water Industries (BDEW) published guidance in the form of a scenario on the introduction of the new rules, which the BNetzA views as a potential industry standard.[21]

With BNetzA decision BK6-22-128, three new objects — grid location, technical resource (TR), and controllable resource (SR) — were introduced as of October 1, 2023. The grid location, which is assigned a specific ID, is used to determine and calculate reactive energy and to monitor compliance with predefined output limits. The TR is used to bring transparency to the technical equipment (such as a heat pump, night storage heater, or wall box) present in a given market location by giving that equipment a technical resource ID (TR-ID). This TR-ID is already in use as part of Redispatch 2.0. The introduction of the TR and use of the TR-ID opens up possibilities such as installing control equipment right where it is needed and ordering control channels (via a control box, for example) from the grid operator as necessary. This enables efficient market communication and control of technical equipment in market locations. The SR is needed to order certain configuration products, such as switching time and power curve definition, for the TR. These configuration products are connected to the control equipment via a control channel. They enable control and configuration of technical equipment in market locations.

While the switching times and power curves are exchanged between market players via traditional market communication, setpoint specifications are exchanged in near real time via the variant of an Applicability Statement (AS) 4 compatible API Web service, which was also first introduced in BK6-22-128. The service is to be available starting on January 1, 2024, on behalf of metering point operators for the other market roles, such as grid operator and supplier, so that setpoints for individual energy installations or grid connections (or SRs) can be specified in near real time (termed "control commands"). As of October 2023, the concrete specifications are still in the consultation phase; an initial version by EDI@energy, the group of experts responsible, is documented here.[22]

4.2. Reflection on theses

The thesis study on the digital transformation of the energy system put forward three theses within the plant communication focus a year ago:

7. **The smart metering system is being overtaken by other solutions in plant communication** ["Theses for the digital transformation of the energy system,", Thesis 7].

The planned smart meter rollout is experiencing delays. At the same time, further information channels are being built and utilized to monitor or control systems and equipment. Advanced manufacturer clouds can already be used to reach a large number of installations through communication technology. Instead of focusing efforts on alternative routes, bringing various solutions together could help to accelerate the digital transformation of the energy supply.

8. **The energy transition requires plant communication based on the latest IT technologies and open documentation** ["Theses for the digital transformation of the energy system," Thesis 8].

Numerous elements of today's plant communication are based on standards that were developed in the early days of telecontrol technology and for which no further development is planned. Modern IoT protocols with open documentation should be used to operate new energy plants.

9. **Modern plant communication enables plug-and-play and cross-stakeholder process automation** ["Theses for the digital transformation of the energy system," Thesis 9].

Due to the enormous number of small and micro-plants that will be actively involved in energy system management in the future, it is no longer possible to manually connect plants. The following measures are required in response: automating connections, automating the change of an aggregator, for example, and automating all processes to ensure operational readiness.

This section addresses the extent to which the individual theses have developed over the past year.

Thesis 7: The smart metering system will be overtaken by other solutions

In the authors' view, the legal and regulatory changes currently taking shape (GNDEW, MessEG, MessEV, universal ordering process, ERD, section 14a EnWG, etc.) are pushing for an accelerated rollout of the SMGW infrastructure with clear goals for expansion even as bureaucratic obstacles are removed or reduced in scope. At the same time, acceptance among end customers is set to rise with the cap on metering charges. Metering point operators (MSBs) will also have to operate with a price limit that has generally remained the same. In addition, grid operators are facing new expenses as they are asked to shoulder greater costs for MSB operation, which can only be put in place with active use of the iMSys capabilities.

Plans call for establishing the SMGW as the central interface for plant communication as an overarching key goal of the GNDEW. SMGW manufacturers are confident that they will be able to produce the number of devices needed for the rollout. However, there is still some uncertainty around factors such as the availability of components from the manufacturer or of specialists to install the devices at the metering point operator site. Broad and interoperable realization of the necessary plant control capability via the SMGW is still several years off. Until then, alternative solutions that are already available on the market will have to fill the gap. At present, there is also a lack of scalable and interoperable solution concepts to connect large-scale plants — both existing ones and those additionally built in the future — outside the low-voltage level via the SMGW infrastructure. The latest publicly funded projects under the DigENet II call for proposals, which closed in early 2023,[23] will likely provide potential answers in the future.

The new and more specific definition of ERD prohibits the use of previous platforms (OEM platforms) for matters of grid operational management and for market use within the scope of EEG/KWKG direct marketing in the future — even if they already exist in practice and expanding these infrastructures could accelerate the digital transformation in principle.

At the same time, connecting decentralized energy plants via this "second" WAN connection (from the iMSys perspective) carries potential cybersecurity risks, as the IT security requirements can vary significantly depending on the system used. These range from the stringent requirements that apply to virtual power plants and larger energy plants (typically starting at 104 MW) with ISO 27001-certified data centers and plant connections secured via virtual private network (VPN) that fall under the KRITIS Regulation to what are known as "balcony" power plants, which are directly integrated via manufacturer cloud and have not been subject to specific rules thus far (note: national implementation of NIS 2 suggests that there will be improvements in this area, along with other developments; for details, see section 6 of this report).

From this standpoint, the current efforts to amend the MsbG again[24] in the context of the German federal government's solar package to establish authority to issue ordinances prohibiting the second WAN interface are understandable in principle as a move to prevent dangerous repercussions for the power supply due to unsecured plant communication. At the same time, however, it must be borne in mind that this communication channel is currently the main one with existing plants. This channel serves at present as the backbone for all of the relevant forms of added value, such as tapping into flexibility and continuous plant and system monitoring by both the operator and third-party service providers — including remote maintenance, which is efficient in terms of personnel resources.

As a result, secure interfaces that practically cannot have any negative repercussions in terms of the security of the supply should continue to be allowed. In the event of a potential risk, a prior evaluation should be performed according to transparent and unambiguous criteria to identify these kinds of situations. This will give the relevant players greater certainty in their planning in terms of both the choice of communication channel via iMSys or the second WAN interface and the design of components. Moreover, if the use of the iMSys infrastructure is to become mandatory, adequate transitional periods should be set so all relevant players can migrate their communications to the new WAN connection on time.

Beyond that, there are already applications today with higher bandwidth requirements, which are served via an end customer's network (local area network, LAN), among other solutions. The performance capacity of the current WAN connection of the SMGW may pose an obstacle to a rapid switchover of these applications. Amid the current situation, the authors therefore recommend that the IT requirements that apply to the second WAN connection of energy plants be tightened as a priority and compliance with the new requirements be monitored, rather than making a near-term push for new and mandatory implementation via the iMSys infrastructure. Alongside the potential technical challenges, it should also be noted that metering point operators already have a big challenge to tackle in the short to medium term in implementing section 14a EnWG.

In this context, the planned addition to section 24 (2) No. 4c MsbG to permit simple active power specifications for control at the market level outside the iMSys infrastructure is a step in the right direction in principle, even though this change will do nothing to reduce the complexity of the overall legal conditions. Furthermore, the GNDEW establishes the overall conditions for a significant increase in SMGWs, as in addition to the required rollout for consumers with over 6,000 kWh of annual power consumption, section 14a EnWG plant operators, and generators of over 7 kW, there is already a requirement to roll out more than 5 million metering locations. Plans also call for the optional installation of another approximately 44 million metering locations. This potential, which has existed since the end of 2022, offers the possibility of a large-scale iMSys rollout in Germany by the end of 2032.

In more concrete terms, the GNDEW has prompted estimates of 15 to 20 million iMSys in 2030 as part of the discussion, which would require many times the level in place at the end of 2022, at approximately 270,000 iMSys (2023 monitoring report[25]), and an estimated 1 million SMGWs by the end of 2023 (according to SMGW manufacturer PPC AG[26]). In the authors' view, a number of measures could contribute to implementing and accelerating this pending rollout, including the following:

- Improved development, expansion, and stability of communication networks for the WAN connection of SMGWs
  - Developing and expanding the 450 MHz network as soon as possible while also accelerating the development and expansion of public mobile networks
  - Evaluate, expand, and refine fallback options in the event that the customary solutions such as mobile networks, dedicated power-line communication (PLC), or broadband networks are unavailable, especially for metering locations not relevant to the grid (e.g., measurements taken only monthly by way of rate use case (TAF) 1). The possibility of making end customer LAN usable for the iMSys infrastructure both securely and at low cost may represent a particular opportunity for these cases.
- Efficient use of installation capacity with digitally supported tools
  - Measure levels in the communication connection on initial setup to eliminate the need for service calls for troubleshooting purposes, followed by close WAN monitoring in the short term (hour range) to facilitate fault resolution
  - Digitally supported installation documentation to accelerate "standard installation" (especially in the new building sector, where the latest generation of meter cabinets is already in place, e.g. VDE-AR-N 4100 compliant meter panels in low-voltage applications)
  - Development and deployment of intelligent planning tools to support decision making during the implementation of the operational rollout by means of continuous consideration of new iMSys inquiries (principle: make full use of the four-month period stipulated by section 34 MsbG)
- Reducing the number of required SMGWs by way of 1:n strategy, especially in multi-family buildings, and expanding capabilities for wirelessly incorporating additional measuring equipment and system units/communication adapters on a more powerful, cross-manufacturer basis via local metrological network (LMN) or home area network (HAN)
- Platform-based one-stop shop for connection users under the auspices of the normally responsible metering point operator and the connection grid operator with access for further relevant market players (such as suppliers, direct marketers, etc.) in order to pool all services together directly when a new grid connection is put into operation, eliminating the need for repeated service calls and bilateral coordination. A medium-term link with the cross-distribution network Internet platform for grid connection requests pursuant to section 14e EnWG and underlying systems at the DSO end seems productive here.

Theses 8 and 9: Modern and open IT-based plant communication with overall plug & play capability

The plant communication of the future will also require the use of current IT and open documentation. At the same time, the technological solutions must feature plug & play capability and enable cross-stakeholder process automation.

EEBus[27] is a current positive example of an open standard from the industry perspective that covers various use cases in plant communication. Implementation is compatible with the use cases explained in VDE AR-E 2829-6-1.[28] However, there has been some criticism from the IT security perspective of its dependence on a stack that is currently commercially available. An overview of plant control for the EEBus ideal case of the digital grid connection point is shown in Figure 6. This approach has been designed primarily for single-family homes thus far.

It is also unclear how individual equipment will be handled or specifically controlled under the home energy management system (HEMS), as not all manufacturers of decentralized energy plants currently rely on EEBus. In the solar segment in particular, SunSpec Modbus is still dominant, and German industry standard SG Ready dominates among heat pumps. In addition, many decentralized energy plants in the low- and medium-voltage range cannot be controlled by grid operators except via switching relays.

Furthermore, plug & play capability has not yet been implemented across the board. For example, EEBus and the FNN requirements specifications control box represent initial concepts or solutions for approaching the objective, but cross-stakeholder automation, including overarching system landscapes, does not yet exist. One potential approach on this point could be the use of digital identities like those currently being pushed for as part of data space initiatives in particular (see section 1).

The authors believe this means an initial set of modern, open standards is available. However, it is not yet possible to predict how these standards will spread in actual use over the next few years. Extensive coordination among the various stakeholders involved, such as plant and system manufacturers and operators, end customers, grid operators, and regulatory agencies, will continue to be needed in order to tap into all of the value added by modern plant communication. To drive the digital transformation, manufacturers in particular will need to be willing to put their efforts into shared solutions instead of forging ahead with their own closed platform solutions. In the European context, the Data Act, which is in its final stages, is a potential enabler of open interfaces, including in the area of plant communication. At the same time, further effort is needed to advance plug & play capability in particular so that the scaling effects of cross-stakeholder automation, especially at the point of initial commissioning and during live operation, can be harnessed.

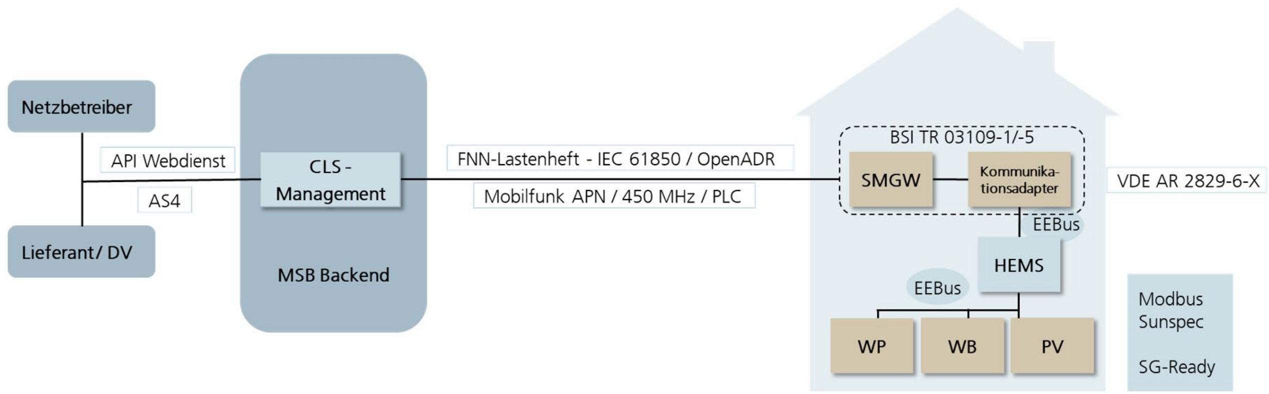
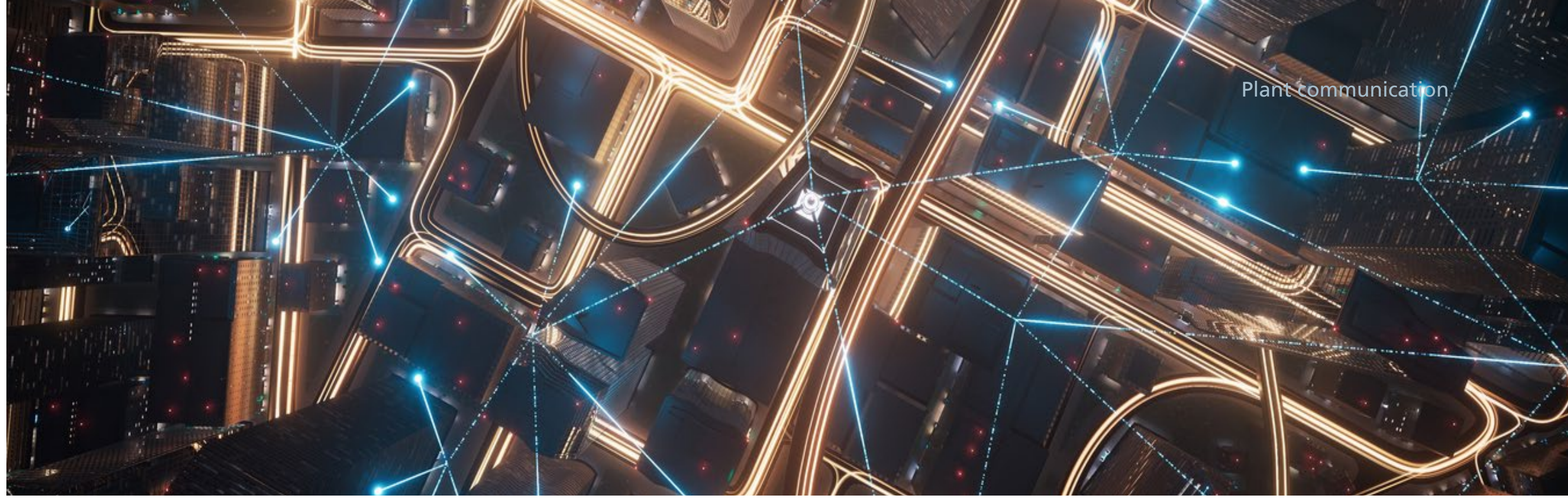


Fig. 6: Schematic of the digital grid connection point for controllability of decentralized energy plants and systems — focus: single-family homes (simplified graphic)



Plant communication

4.3. Initial findings

The legal and regulatory changes occurring during this reporting period represent clear specifications and goals set by the government for the iMSys rollout. This robust commitment to the future use of the iMSys infrastructure for plant communication offers a clearer picture of the objectives for plant control for all of the stakeholders involved. End consumers and operators of smaller energy plants are also expected to grow more accepting of the use of the iMSys infrastructure as a result of the cap on metering charges.

However, some details, such as the long-term overall conditions for the use or continued use of the second WAN connection, remain to be clarified and will require further specification in the near future. The actual connections of the iMSys infrastructure from the communication technology perspective also require rapid development and expansion and the strengthening of the underlying telecommunication networks in order to make expansion of use feasible as a possibility. This is especially true of the public telecommunication networks, but in the long term also applies to the dedicated 450 MHz infrastructure.

To efficiently implement the rollout with a significantly larger number of SMGWs even as installation capacity is increased to a limited extent, digitally supported tools should also be used on a targeted basis during installation, configuration, and operation. This holds the potential to reduce the time spent, along with personnel expenses.

The development and use of interoperable interfaces with plug & play capability should be prioritized in the process, including — and especially — in cooperation with manufacturers. On this point, there is particular need for concrete objectives for cross-stakeholder automation in order to harness the full advantages of the digital transformation in plant communication.

One use case that has not yet been specified is the future connection of large-scale facilities outside the low-voltage level via the iMSys infrastructure. Further research and development will be needed in this area.

Focus on plant communication — current CINES activities

1. Plant communication under the conditions of grid redevelopment in the concluded BMWK-funded project SysAnDUk — https://www.iee.fraunhofer.de/de/projekte/suche/2019/sysanduk.html
2. Development of resilient virtual power plants in the current BMWK-funded project SecDER — https://secder-project.de/
3. Incorporation of entities authorized to control equipment into the iMSys infrastructure via open source solutions, BMWK-funded collaborative project MeGA — https://www.enargus.de/pub/bscw.cgi/?op=enargus.eps2&q=mega&v=10&id=30346847

5. Grid operation and planning

Challenges in grid operation and planning

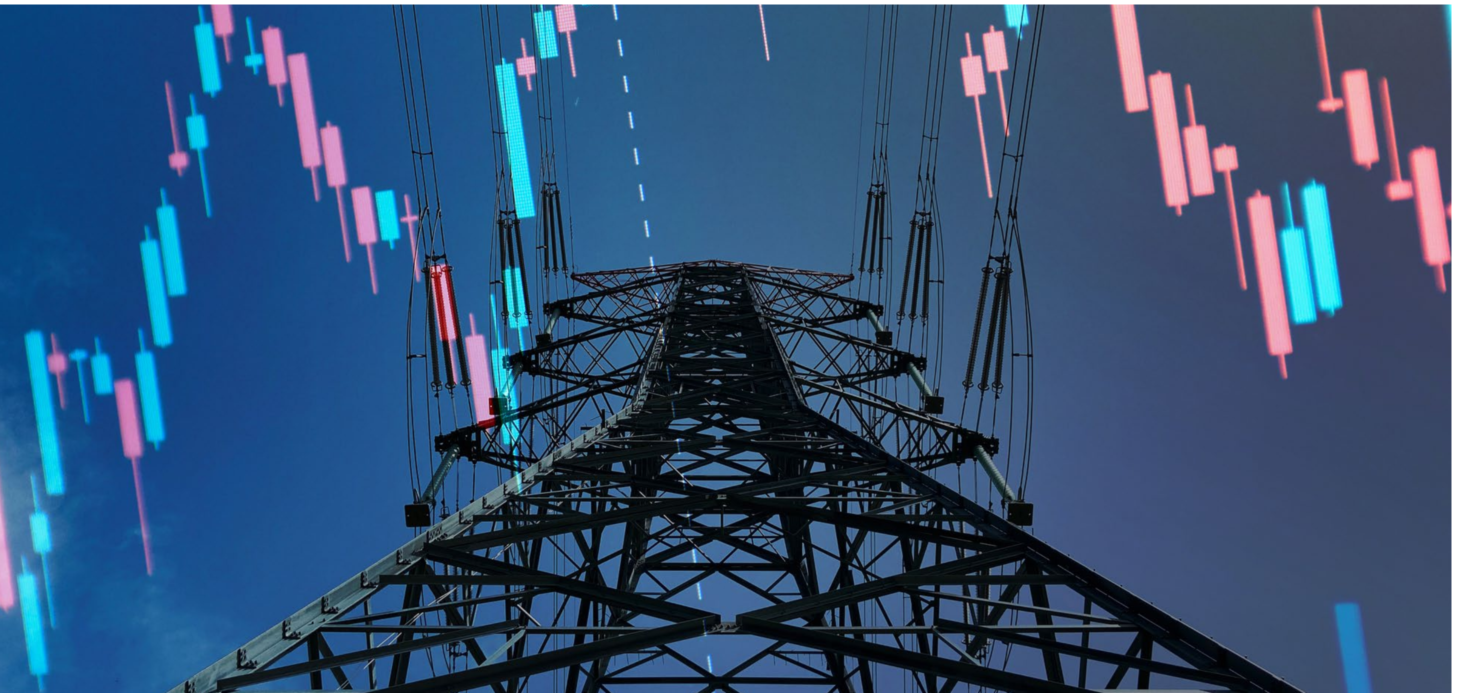
The transition to a climate-friendly energy supply is inseparably linked with the transitions in transportation and heating. Especially for distribution networks, this means more than just that power generation capacity in the form of wind and solar energy is being brought online. As the heating and transportation sectors go electric, new consumers, some of them large, such as electric vehicles and heat pumps, are also being connected to the lowest levels of the grid.

That means new challenges for planning and operation — but also opportunities. According to conventional planning principles, a typical local grid station with a rated output of 400 kVA could supply some 200 to 300 households. Assuming a typical EV charging station with 11 kW of connection power, that local grid station would already be overloaded if there were just 36 vehicles charging at once, without supplying any other consumers at all. A similar picture emerges when we consider heat pumps and power generation with solar panels.

At the same time, EVs and heat pumps are generally highly amenable to control as consumers, and they can be charged at times of high generation and/or low loads. Many homeowners are already using solar panels to generate their own power today for economic reasons so they can charge their EVs with solar optimization and keep their power costs as low as possible. In addition to pure load control, many solar panel owners are also investing in stationary batteries and potentially also mobile batteries in EVs (V2H) to boost their self-generation rates. Aside from these decentralized incentives, it can also be necessary to control consumption and generation in ways that serve the grid when critical situations arise. Tools such as the adjustment to section 14a EnWG for controllable consumption devices and Redispatch 2.0 create the framework for using customer systems and equipment in ways that benefit the system as well.[29]

From the standpoint of grid planning, the current planning principles for median consumption are no longer adequate. Instead, there is a need to determine the specific supply responsibility for each section of the grid in detail. This forms the basis for generating time series in a way that includes the relevant market-driven operating style of those connected to the grid, along with potential specifications by the grid operator. The supply scenarios act as the foundation for demand-driven, predictive, and cost-optimized grid planning.

Even tapping into flexibility will not eliminate the need to expand the grid. Still, new planning methods can make that expansion as cost-effective as possible, at least. And that is a critical point, particularly since more and more households are striving to use self-generated electricity. This also reduces the consumption of power transmitted via the grid, so the grid costs are spread across fewer kWh.



5.1. Overall regulatory environment

Grid planning and operation are subject to clear overall regulatory conditions. There have been some highly interesting developments in this area over the past year.

Adjustment of section 14a of the of the Energy Industry Act (EnWG) for controllable consumption devices and universal ordering process:

The provisions on grid-oriented control of controllable consumption devices and grid connections pursuant to section 14a EnWG state that operators of electricity distribution networks and suppliers, end consumers, and those connected to the grid must enter into agreements on the grid-oriented control of controllable consumption devices or grid connections for those devices. In return, grid fee reductions are established. The law was first drafted in 2011 and then revised in 2016. After that, no further changes were made until 2022. As of January 1, 2023, the legislature assigned authority for making decisions on the provisions relating to grid-oriented use of controllable consumption devices to the German Federal Network Agency (BNetzA). At the same time, the BNetzA established a new set of rules for the processes involving control actions associated with smart metering systems in the form of the universal ordering process, which applies as of October 1, 2023.

The new version of section 14a, which deals with "grid-oriented control of controllable consumption devices and grid connections" and reduces grid fees to prevent grid overloading, was adopted in December 2023 with an effective date of January 1, 2024. The goal was greater regulatory clarity and certainty surrounding the supply in spite of the rising demand for electricity created by electric vehicles, heat pumps, and battery storage. The changes encompass the exact definition of the authorization to control equipment and, in return, a guarantee of immediate grid connection for operators of controllable consumption devices. Documentation obligations and grid expansion requirements were also introduced for when control measures have been taken or further measures are anticipated.

The key issues paper published by the Federal Network Agency beforehand has already triggered debate, primarily due to lack of clarity around some terms and distorted media reports. The grid operators agreed that temporary control interventions would be necessary up until the grids are expanded, but they had concerns about the new law. Terms like "static control" and "dynamic control" were perceived to be ambiguous, and the introduction of the "technical measurement determination" was criticized due to high costs. Installing measurement technology across the board was viewed as an unnecessary step. Instead, the grid operators would prefer to see ongoing use of other methods, such as state estimation, to determine the exact capacity utilization. Industry experts, associations, and representatives of interest groups submitted suggestions for changes as part of a several-stage consultation process.

One key feature of the new provisions is that they make it clear that a complete shutoff is not allowed. Ruling chambers 6[30] and 8[31] determined that operators of controllable consumption devices can choose from among three modules, which affect the grid fees:

- Lump-sum reduction (general discount) in grid fees (Module 1)
- Percentage reduction in the unit price (Module 2) if there is a separate measurement of consumption by a controllable consumption device
- Incentive module (Module 3) with grid fees that vary by time in addition to Module 1.

Concretely, grid-oriented (dynamic) control by the distribution network operator is allowed starting on January 1, 2029, at the latest if a peak period has been identified using measuring technology and a reduction in the amount of power drawn from the grid is triggered within three minutes. It must be ensured that at least 4.2 kW of power can be drawn from the grid. Grid-oriented control always takes precedence over other forms of control, such as market-based load control. There will be a transitional period for plants and equipment that began operating before January 1, 2024.

Current developments in the Redispatch 2.0 process:

Financial compensation for redispatch measures, including curtailment of generation plants, has been a requirement for electrical grid operators since October 1, 2021. Based on the recommendations made by industry association BDEW

on communication processes, data delivery obligations, and grid operator coordination that are suitable for the mass business, BNetzA ruling chamber 6 issued three determinations on Redispatch 2.0, declaring the new rules to be legally binding. Financial compensation and the stipulated processes are already successfully in practice for plants connected within the transmission system.

By contrast, pilot projects for application to plants in the distribution network were concluded as of August 1, 2023. Instead, the "BDEW transitional solution" is practiced, in which the financial compensation is provided by the balancing group manager with additional compensation provided by the connection grid operator where the financial compensation is not provided by the grid operator. However, there has been criticism of the transitional solution owing to the lack of legal certainty involved. Efforts are also under way to design Redispatch 2.0 to be a procedure that is suitable for the mass business in order to accommodate the challenges involved in the planned and necessary build-out of renewable energy. At present, however, there is no expectation of implementation under the given circumstances. With this in mind, an expert was commissioned to consult on concrete suggested changes in order to take suggestions for the further development of the determination on Redispatch 2.0 into account based on the findings from the pilot projects.

While the Redispatch 2.0 process is still in the implementation phase, active work is already under way to take it to the next stage, known as Redispatch 3.0. Research projects and studies by entities including transmission system operators are devising suggestions for how this is to be designed. Since Redispatch 2.0 typically relates only to facilities with installed output of 100 kW or more, Redispatch 3.0 begins by addressing the flexibility potential of small and micro-plants. In addition to generation equipment, the goal is to also use other energy systems such as heat pumps, home storage, and electric cars to stabilize the grid. A financial incentive for voluntary participation by plant and equipment operators has been proposed.

The current phase involves designing the processes and system architecture that are viewed as necessary in order to realize these plans. To reduce the complexity involved in the large number of small and micro-plants, aggregation objects that pool together controllable consumption devices have been proposed. Both plant master data and dynamic data such as measurements and forecasts are relevant for this.

5.2. Reflection on theses

Against the background of recent developments, experts were invited to reflect on the theses put forward in the study of the digital transformation of the energy system.

Thesis 10: Digital transformation is a core area of expertise in future power grid operations

In principle, there is still broad agreement with this thesis. The experts' statements offer interesting insight into various current aspects of the digital transformation in the operation of the grid. For a more detailed treatment of the question of whether digitalization capabilities are business-critical, the various aspects are elucidated and distinguished first.

The experts view "digital transformation" in the context of grid operation as generally meaning the implementation of live data that play a crucial role in monitoring the network. Another aim of this kind of digitalization is to make as many components as possible controllable, for example to enable faster troubleshooting. A third goal is to develop digital visualizations of the networks and their assets to enable faster integration of IT and OT and bring increased transparency within the grid. Platforms such as Envelio and PSInGo are used to advance the digital transformation and boost the efficiency of grid operation.

The experts' comments during the roundtable discussion highlight the challenges and potential conflicts of goals inherent in the digital transformation of electricity grid operation. There is a particularly critical view of higher utilization of grid capacity, as grid stability remains of paramount concern. For example, the experts stressed that digitalization alone is unable to significantly increase grid capacity. Controlling the consumption side in the event of a peak is viewed as an emergency solution that should only be utilized if the grid itself cannot be expanded fast enough. The experts also stressed that automation alone is not (yet) able to substitute for the necessary control and monitoring of the network.

Use of highly qualified specialists is still necessary across all areas of grid operation. The aspects of capabilities, expertise, and personnel are also clearly expressed in other statements made by the participants. Specifically, they are concerned with the time, effort, and expense involved and with the additional requirements that the digital transformation has brought. The experts point out that the implementation of the digital transformation will initially require additional resources and specific capabilities. Digitalization does not free people up for other tasks right away; quite the opposite, in fact. Capabilities must be built and the transition made even as regular operations are ongoing. Merely considering technological advances in grid operation in isolation is insufficient — the processes and business models involved also require adjustment. Data can also be a source of new value. This is associated in some cases with big internal changes, and it is very time-consuming. With this in mind, all grid operators should devote their attention (and other resources) to this transformation as soon as possible.

In addition to putting together internal teams, collaboration with external service providers is viewed as an important step in executing digital projects effectively. These organizations are already working with service providers such as Count and Care, Venios, and Smight on a variety of points. There is considerable dependence on these service providers, as they contribute specialized skills and expertise. However, the experts also point out that it may be prudent to bring these responsibilities back into the company later on. Use of external service providers allows the companies to benefit from their expertise and implement their digital projects effectively.

Thesis 11: Decentralized energy transition equals comprehensive digital transformation right down to the lower grid levels

Just as the 110 kV level has undergone a comprehensive digital transformation in recent decades, grid operation without this kind of data collection and monitoring is no longer conceivable going forward, including in medium- and low-voltage networks. However, digitalizing the widespread and fragmented low-voltage level in particular in this way would be associated with steep costs, which is why an optimum balance of grid expansion, measurement and control technology, and state estimation is being sought.

According to the experts' statements and current regulations (section 14a EnWG), adequate observability is to be achieved through 20% measurement penetration of the network.

In addition, plans call for a significant share of prosumers to be controllable and available to provide flexibility.

However, the drawbacks of this digital measurement technology include the fact that it often runs via a central system operated by the metering point operator and is not directly available for grid management. The great heterogeneity of data sources is also a huge challenge when it comes to harnessing these data on a standardized basis for monitoring and control purposes.

Implementation and integration into their own processes and system landscapes present various obstacles for grid operators. These statements make it clear that the Act to Restart the Digitalization of the Energy Transition (GNDEW, May 2023) is not necessarily suitable for simplifying grid operation and streamlining bureaucracy in the future, as there are still too many different systems and data sources that need to be merged together. The technical details are the crucial challenge here. Nevertheless, all of the experts agreed that they could endorse the thesis per se and also see that it is necessary. The speed and degree of implementation also depend on the ramp-up on the feed-in side (solar) and among consumers (focus on electric mobility and heat pumps) in the relevant low-voltage networks. Priorities can be set and experience gleaned here.

In summary, these people's statements make it clear that a decentralized energy transition will require across-the-board digital transformation, right down to the lower grid levels. The challenges lie in standardized use of different data sources, connecting all of the data, and preventing conflicts on the control side. The digital transformation of the grid levels is viewed as a lengthy process, but one that is driven by factors such as climate neutrality. These findings are associated with the previous summary, which emphasized the importance of the digital transformation as a core competency in the future operation of electrical grids.

Thesis 12: Timely implementation of the energy transition can only succeed by ensuring the complete digital transformation of planning and approval processes

This thesis focuses on the connection between the complete digital transformation of planning and approval processes and the timely implementation of the energy transition. The number of connection requests has risen sharply, particularly due to the introduction of "balcony" power plants, making timely manual processing no longer possible. The experts present concurred with this view. Staffing capacity has largely reached its limit, which has prompted the introduction of automation tools in some instances to keep things under control. Going forward, plans call for the automation of all processes relating to grid planning and approval to prevent application backlogs and remove obstacles to the energy transition.

In summary, the experts' statements make it clear that the complete digital transformation of planning and approval processes is a crucial factor in the timely implementation of the energy transition. Digitalization will enable efficient handling of the rising volume of tasks and requests, particularly those relating to connecting balcony power plants and the low-voltage grid. Bringing together various data sources and automating processes are highly important in preventing bottlenecks and driving the energy transition. These findings are associated with the summaries and theses that have been put forward previously.

The need for a comprehensive digital transformation has already been stressed in relation to core areas of expertise in the future operation of electrical grids and across-the-board digitalization right down to the lower levels of the grid. The digital transformation of planning and approval processes is another important aspect of the energy transition, in which uptake of new and digital technologies plays a key role. Bringing together data from various sources and automation of processes will help to make grid operation more efficient and prevent bottlenecks. A holistic view of all aspects of the digital transformation across electricity grid operation is crucial in order to enable the timely implementation of the energy transition.

5.3 CINES activities in the area of grid operation and planning

The digital transformation in grid operation encompasses the implementation of live data, the controllability of the grid, and the development of digital representations. The shift to digital processes requires additional resources and specific expertise, which calls for the involvement of both internal teams and external service providers. Working with external service providers unlocks the possibility of bringing in specialized expertise and implementing digital projects effectively. The digital transformation is a way to make grid operation more efficient and more stable, but it also requires a holistic view in order to overcome potential conflicts of objectives and challenges.

The new version of section 14a EnWG creates a long-awaited legal basis for the further digital transformation and addition of flexibility to the electricity network. The clarification that no connection requests can be refused based on peak loads in the grid is a particular milestone. Creating the necessary processes and infrastructure for control in a way that serves the grid is a challenge that requires a complete digital transformation. Further collaboration and the building of additional competencies will both be necessary. Further developments in the grid fee system and incentive regulations would create additional positive momentum in this regard.

The text below mentions a few sample projects from the cluster of excellence.

Focus on grid operation and planning — Current CINES activities

1. StraZNP — Strategic and Targeted Grid Planning is based on scenarios for the responsibility of supplying power, for which relevant time series are established.
2. AI4Grids — AI-based planning and operational management of distribution networks and microgrids for optimum integration of renewable generators and fluctuating loads within the scope of the energy transition.
3. Redispatch 3.0 — Redispatch and marketing of unused flexibility from small and microplants behind smart metering systems.

6. Cybersecurity

The increasing digital transformation of the energy supply in Germany brings many advantages, and with them also substantial risks. Cyberattacks on critical infrastructure, especially in the energy sector, have become a serious threat. To meet this challenge effectively, cyber-resilience will become an increasingly crucial factor going forward.

Cyber-resilience in the energy supply

Cyber-resilience is a system's ability to detect and repel cyberattacks, recover afterward, and ensure the continuous availability, integrity, and confidentiality of critical processes. In the context of the energy supply, this means the energy system must be able to ensure that the supply of energy is maintained even in the event of a cyberattack and resume normal operation as soon as possible.

The NIST Cybersecurity Framework[32] was developed to support the implementation of cyber-resilience within organizations. It comprises five phases, known as functions: Identify, Protect, Detect, Respond, and Recover. The aim of this structure is to help develop and implement a comprehensive and effective cybersecurity strategy.

Fig. 7: NIST Cybersecurity Framework[33]

Identify: The Identify function encompasses identifying critical infrastructure, determining the threat situation, and performing analyses of effects between the ICT infrastructure and the supply process. This is crucial to developing an effective security strategy.

Protect: This step comprises measures to safeguard critical infrastructure. It includes access controls, encryption, training for employees and other security measures that help to prevent attacks.

Detect: Early detection of attacks on the organization's ICT infrastructure is the focus of this function. This includes implementing surveillance mechanisms, intrusion detection systems, and other technologies for rapid identification of security incidents.

Respond: This phase comprises the response to an identified security incident. This includes developing emergency plans, training for the security team, and taking steps to curb and eliminate threats.

Recover: To be able to restore normal operation as soon as possible following a security incident, it is important to prepare and test backups and recovery plans. The Recover phase also includes measures to prevent similar incidents in the future.

Situating cyber-resilience requirements in a framework like this provides a structured approach to enhancing cyber-resilience. Cyber-resilience should be viewed as a cycle that enables continuous assessment of security practices, and thus ongoing improvement and adaptation to the ever-changing threat landscape. This is crucial in ensuring that the primary protective goals of integrity, availability, and confidentiality of critical infrastructure are met and in minimizing the potential impacts of cyberattacks.

New regulations and laws

Measures falling within the Identify and Protect functions were the primary focus for companies in the area of critical infrastructure in the past, but now the Detect, Respond, and Recover phases are increasingly taking center stage in terms of cybersecurity strategy. Current and planned legislation is a significant driver of this development.

There have been tremendous advances in the laws on cybersecurity in critical infrastructure (known in Germany as KRITIS) in recent years. Taking EU-wide regulations as a basis, national laws in Germany stipulate extensive measures and obligations for KRITIS operators, both now and into the future, especially in the fields of cybersecurity and cyber-resilience.

IT Security Act 2.0

The IT Security Act 2.0 has been in force since May 2021. It significantly expands on the IT Security Act that had been in force until then and the BSI Act. The new law sets out more obligations for a larger category of critical infrastructure operators while also tightening requirements in relation to measures and processes involved in cybersecurity. The thresholds for what counts as KRITIS have been lowered, which, in the energy sector, applies primarily to power generation. As a result, even smaller energy suppliers fall within this category. The number of KRITIS installations in the energy sector has also risen. Beyond that, existing KRITIS operators now have new obligations to report to the German Federal Office for Information Security (BSI) and are directly obligated to register with the BSI as KRITIS operators.

But the change with the most far-reaching implications for KRITIS operators was the obligation to introduce intrusion detection systems. This requirement took effect as of May 31, 2023. Under the new rules, operators of critical infrastructure are required to establish concrete measures in relation to technologies, organization, and personnel to implement the intrusion detection systems.

EU NIS 2 and NIS 2 Implementation Act

The EU NIS 2 Directive was adopted together with the EU CER Directive in 2022 and entered into force at the start of 2023. This directive establishes the European framework for critical infrastructure operators, setting EU-wide minimum standards for cybersecurity in critical infrastructure sectors. The number of sectors classed as critical has also been increased to 18 in all, 11 of them deemed highly critical, especially the energy sector and seven "other critical sectors." Companies are also classified as "essential entities" and "important entities" based on their size and sector affiliation.

The binding minimum requirements encompass a number of measures that can also be matched to the various areas of the cybersecurity framework. This includes concepts for risk analysis for information systems and security for information systems (Identify), incident management (Respond), and crisis management and business continuity (Recover). The new rules will be transposed into German law via the NIS2 Implementation Act, which must be adopted by October 2024. The law is an amendment act that will mainly impact the BSI Act.

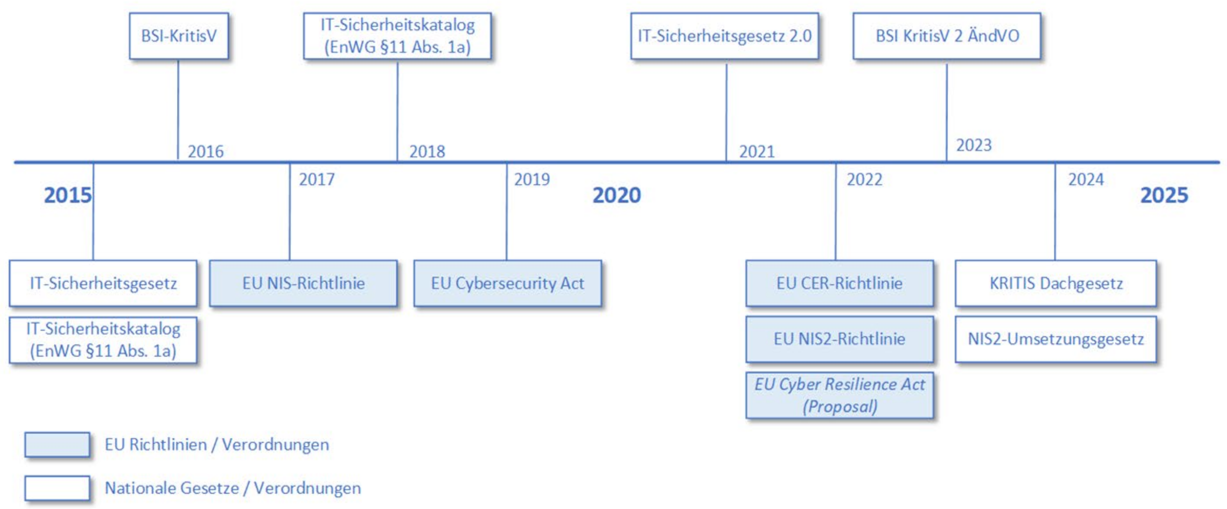


Fig. 8: Development of legislation on cybersecurity in the KRITIS sector (authors' view)

Cybersecurity

EU CER Directive/German KRITIS Umbrella Act
The EU CER Directive was adopted in late 2022 together with the NIS2 Directive. It regulates requirements with regard to resilience in critical infrastructure across the entire EU. Binding measures for companies and state entities are also established. The transposition to national law must take place by 2024 in this regard as well. In Germany, this is covered by the KRITIS Umbrella Act. The CER Directive focuses to a particular degree on resilience through physical protection.

The KRITIS Umbrella Act will set rules for the operators of critical infrastructure with an eye to implementing measures to increase cyber-resilience. These measures will cover all areas of the cybersecurity framework. For example, regular in-house risk analyses (Identify), enhancing physical protection (Protect), crisis management (Respond), and business continuity management (Recover) are identified as measures that must be implemented at KRITIS organizations in compliance with proportionality.

EU Cyber Resilience Act
There are plans for another EU directive, the EU Cyber Resilience Act, which currently exists in draft form dated September 15, 2022. It sets general standards for products with digital elements, including software and hardware products. The new law also encompasses the implementation of the "security by design" approach with appropriate measures across the phases of design, development, and production. For example, the draft obligates manufacturers to close security gaps across the entire product life cycle for a period of up to five years. It also encompasses an obligation for manufacturers to report any vulnerabilities. In addition, even more stringent requirements will apply in the future to products that the draft classifies as critical. While the regulations and laws mentioned above are primarily aimed at the operators of critical infrastructure, the Cyber Resilience Act expressly extends greater obligations to manufacturers.

6.1. Reflection on theses

The thesis study on the digital transformation of the energy system put forward two theses in the area of cybersecurity:

Thesis 12: Cyber resilience will replace cybersecurity

The design approach to resilience therefore complements the security approach with the addition of intrusion detection, response and recovery. The idea is primarily driven by the fact that security mechanisms fail, systems are attacked and still need to remain in operation, or operations need to be resumed as quickly as possible.

The topic of cyber-resilience has reached the operators of critical infrastructure as a result of the obligation to introduce intrusion detection systems. At the same time, the discussions held with experts and stakeholders from the energy supply segment reveal significant differences in status. In general, it is apparent that the term "cyber-resilience" is highly present for companies of a certain size. This is also reflected in the expert interviews, according to which there is great variety in the status of implementation of cyber-resilience concepts.

In addition to the necessary measures in relation to intrusion detection systems, many companies are currently focusing on purely preventive measures to protect critical infrastructure. At this point, very few operators have implemented additional incident response processes or established business continuity plans and fallback solutions. One factor that is viewed as essential in establishing the measures arising from IT Security Act 2.0 and the subsequent laws is that the management level at these companies must build the knowledge and understanding of cyber-resilience to be able to make the necessary structural, personnel-related, and technological decisions.

Views on the stipulated process for the introduction of intrusion detection systems also varied, especially in relation to the mandatory audits, which are not always considered to be a productive way to enhance cyber-resilience within organizations.

Introduction of intrusion detection systems encompasses both company IT infrastructure and the OT level, with its immediate proximity to processes.

At the same time, there is a challenge in that owing to the particular nature of the OT infrastructure, the expertise needed to consider both levels is not present across the board, while integral monitoring of IT and OT does require that this expertise be cultivated. To monitor the OT level, operators would additionally need to perform an initial survey to identify the components and assets with regard to hardware and software status and the communication channels involved. In many cases, however, there is no detailed monitoring of OT infrastructures because systems are closed off from each other; all that is monitored is the interface to the overall system. Going forward, changes will be needed in this regard due to advances in the digital transformation of the OT level.

There is also a great deal of variance with regard to the status of introducing intrusion detection systems. The survey responses and discussions with experts yield a picture in which the majority of companies meet the minimum requirements and have at least begun collecting log information from network devices. Some companies have taken this process one step farther by introducing an SIEM (security information and event management) system and incorporating this monitoring information. A complete incident response process is even already in place in some cases. This goes hand in hand with the establishment or expansion of internal company security operation centers (SOCs) relating to monitoring the OT level. However, there is a further challenge here for smaller companies, as they generally do not have the resources to establish SOCs of their own, but externally operated SOCs are typically not effective in achieving their objectives. Simple solutions that handle these tasks with full automation if at all possible will be a major focus in this domain in the future.

The IT Security Act addresses the necessary aspects of technologies, organization, and personnel in meeting the requirements, including — and especially — as they relate to intrusion detection systems. In particular, the availability of well-trained staff to meet the complex requirements involved represents a major challenge for energy supply companies, as it cuts across topics relating to IT and OT components and the process perspective alike. Efforts to bring additional human resources on board and, even more importantly, provide existing staff with further training will be needed. The status of implementation here ranges from establishment of accessible awareness training activities for individual employees to mandatory participation in awareness training for all employees and extends to companies that provide extensive training across the Detect, Respond, and Recover functions for all employees working in telecontrol and other forms of control technology.

Thesis 13: Reliable energy infrastructures require reliable communication networks

Communication networks are increasingly becoming an integral part of the energy infrastructure. Paradigms of secure and reliable energy supply, such as the N-1 principle, must also be taken into account in the planning and operation of the necessary communication infrastructures in the future. Various communication technologies (such as 450 megahertz as backup) will be used for this.

The communication networks are also affected by current and future legal specifications. The draft versions of the KRITIS Umbrella Act and the NIS2 Implementation Act both call for operators to implement resilient communication infrastructure and to establish and use secure emergency communication systems.

To this end, the various grid operators have created infrastructure in recent years to permit communication based on the 450 mHz frequency in case of incidents. Based on this radio solution's properties as a secure, cost-effective communication channel, it is also increasingly being used as the sole connection for decentralized generation facilities.

In general, the overall picture based on feedback from the expert interviews is one of advanced implementation of completely redundant connections of plants and infrastructure, albeit in some cases limited only to larger decentralized systems, all the way up to exclusive redundant connection of central systems.

The status of the communication network, particularly as regards quality of service, was described in some cases as full coverage for the system with ICT and futureproof overshoot in communication capacity with very rare disruptions or instances of low connection quality. In the majority of cases, full to nearly full coverage of the system with ICT connection and adequate accessibility and reliability for critical services is attested. In a few isolated instances, low coverage of the system with ICT is described, in tandem with frequent connection disruptions, high latency times and data losses, and low availability and accessibility.

To achieve the paradigm shift to N-1 security in communication technology, the planning and conceptual design of ICT infrastructure will need to be adjusted. Jointly coordinated planning of communication infrastructure is a primary area of focus when supply infrastructure is expanded or replaced. Implementation of shared plans typically takes place within individual companies. However, this is made more difficult by the fact that the standards underlying the necessary processes (such as IEC 62443) describe the individual roles, but do not include the integrator role.

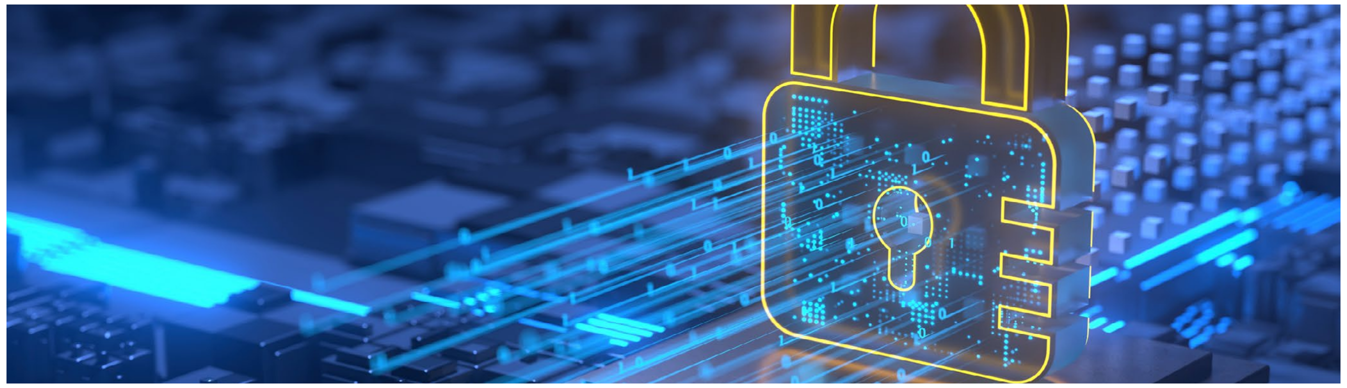
6.2. Initial findings

The legal requirements laid down by the EU and the national laws arising from them increasingly focus on enhancing cyber-resilience at companies involved in critical infrastructure sectors. These measures extend across all of the phases of cyber-resilience. At present, the focus has mainly been on introducing intrusion detection systems. The picture that emerges with regard to the status of implementation is highly varied, ranging from minimum requirements being in place to consideration for further processes relating to incident response and business continuity management.

On the topic of cyber-resilience, the human factor must be considered in tandem with processes and technologies. Especially for smaller companies, there is an additional challenge inherent in implementing required measures and the processes they entail with the existing scanty human resources, as additional personnel is difficult to impossible to acquire. In many cases, bringing in external service providers for activities such as operation of an SIEM or SOC is not productive, either. Separately from those considerations, training and continuing education for new or existing personnel is a hugely important topic with regard to the complex challenges involved in cyber-resilience, and most companies have not yet addressed this need.

Focus on cybersecurity — current CINES activities

1. Cyber-resilient electrical grids in the context of the latest research project funded by the German Federal Ministry of Education and Research (BMBF), RESIST — Resilient Power Grids for the Energy Transition — https://s.fhg.de/B56
2. Development of assessments and continuing education programs on the topic of cyber-resilience in the energy supply within the scope of the Fraunhofer Academy Cybersecurity Training Lab
3. Training development in the area of effective responses in the KRITIS sector of energy



7. Summary and outlook

The actions recommended in our thesis study called for extensive digital transformation to enable greater cost efficiency and speed in transforming the energy system. As this report shows, extensive regulatory measures have been put forward and adopted at both the national and EU levels. The authors believe many of them go in the right direction, and the various points addressed often also align with the objectives of the recommendations under discussion. On the whole, the legal and regulatory changes thus draw a significantly clearer picture for many individual points, so they can act as the basis for promptly addressing specific points. A distinction should be drawn between national specifications, which require companies that are now affected to take specific actions, and EU specifications, which must first be transposed into national law.

The expert interviews underlying the analysis affirm the positive overall view of the changes that have occurred in the overall legal and regulatory conditions. Even so, it is clear from this analysis that although many improvements have been made at the detailed level, there is still no big-picture view. The digital transformation of the energy system is too complex to allow for a rollout based on a rigid project plan. With this in mind, the authors welcome the agile approaches that have now also been incorporated into laws such as the GNDEW. For their part, however, the authors also note the lack of a clear big-picture view to guide the next steps in the digital transformation of the energy supply. This kind of vision for the future would also need to incorporate room for agile refinement and fine-tuning of details while focusing on shared further development of the various secondary aspects involved.

On the whole, individual changes such as those made to section 14a EnWG have brought much-needed clarity to many areas that had previously remained uncertain. Clear overall conditions thus make investment decisions significantly easier for companies. The authors also perceive a significant increase in digital transformation activities within the industry.

However, many details still need to be clarified, including the inclusion of large-scale facilities such as wind farms in the SMGW infrastructure. An overall vision for the digital transformation as mentioned above would be helpful on this point as well.

Now, as the next step, both equipment manufacturers and individual players within the energy sector will have to take action to drive implementation in line with further changes in the regulatory framework in the years to come. In this regard, the authors note a certain protectionism in relation to data use and systems at the individual companies. With an eye to the digital transformation of the entire energy sector, this behavior poses an obstacle to the implementation of the next steps. Transposition of the Data Act may be one solution here.

This means a number of aspects are required if the digital transformation of the energy transition is to be brought up to the necessary speed:

- An overall vision of the digital transformation is needed as a concept for the various stakeholders to work toward together.
- The digital transformation of the energy system requires a more open approach to data and information so that the systems used by different stakeholders and producers can work together in making the greatest possible contribution to implementing the energy transition.
- Digitalization remains an integral part of implementing the energy transition, but the cyber-resilience required of critical infrastructure must be present as well.

Annex

8. Annex

8.1. List of figures

8.2. References

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Notes

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