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The European Grid Deep Dive

Which grid problems will venture-backed startups solve – and which will be solved by incumbents, infrastructure capital, or politics?

A joint investment thesis by Vireo and High-Tech Gründerfonds (HTGF)

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SUMMARY

Ten takeaways

Europe is spending the decade electrifying everything while re-building its generation fleet around weather-dependent renewables. The infrastructure in between – the electricity grid – was designed for neither. This paper maps where that mismatch creates opportunities for venture-scale companies, and where it doesn't. We use Germany, Europe's largest and in many ways most constrained grid market, as the reference case, and draw comparisons across Europe wherever they change the picture. For readers short on time:

- **The bottleneck has moved from generation to grid.** Renewables are currently the cheapest source of new electricity generation; connecting, balancing, and protecting them is now the constraint: Germany curtailed ~9.4 TWh of renewable power in each of 2024 and 2025.[1]
- **Not every grid problem is a startup problem.** Some problems will be solved by politics, some by infrastructure capital, some only once a market exists to pay for them. For every segment we ask: can a startup win here? Where the answer in our opinion is no, we say so.
- **Smart meters are necessary, not sufficient.** Smart meters covered 5.9% of German metering points at 30 June 2026, and BNetzA has opened enforcement proceedings against operators that had not started the mandatory rollout. Metering remains a binding constraint, but data access, controllable devices, aggregator access and customer contracts are separate gates.[2] The venture opportunity is in what meters enable, not in competing for the regulated meter itself.
- **Industrial and commercial demand response is the near-term flexibility bet we're most confident in.** The case is reinforced by increasingly frequent periods of oversupply: negative prices occurred for a record 573 hours in 2025, while 17% of all hours in April 2026 cleared below zero.[3] These price signals create a growing incentive for large consumers to shift, curtail, or reschedule electricity use. Industrial sites are large enough that a handful of customers can generate meaningful revenue, and the €/site savings math already works today rather than depending on a future rule change. The regulatory picture is more mixed: German network fees still reward constant consumption, BNetzA's May 2026 AgNes concept keeps that relief in place through 2031, and the future industrial tariff design is deferred to a 2027 decision.[4] Any reform that rewards flexibility should be viewed as upside rather than a base-case assumption.
- **Heat is a large, growing and investable flexibility resource.** Hot-water tanks, large heat pumps, electric boilers and thermal storage can shift electricity demand across time, and the pool grows as heating electrifies. The investable layer is the control software that co-optimizes these assets with heat demand, electricity prices and grid constraints, not ownership of heating infrastructure. Building-portfolio optimization is commercially validated; district-scale multi-asset control is earlier and still open.
- **Carmakers are launching residential V2G as closed packages, and consumer smart charging already has incumbents at scale.** The first commercial offers work only within one manufacturer's combination of vehicle, charger and tariff. The startup openings are what those packages don't reach: depot and

heavy-fleet charging optimization, scheduling that accounts for battery wear, integration across manufacturers' closed systems, and supplying the technology inside the packages themselves. Business models should earn money from smart charging alone, with feed-in revenue as upside.

- **In flexibility, the moat is the aggregation infrastructure, not market access.** Small assets can already trade on spot markets in 0.1 MW increments, and balancing products permit aggregation above a 1 MW minimum, so access to markets is not defensible. What defends is the operational stack that turns thousands of assets into reliable market positions: connectivity, forecasting, dispatch, settlement and balance responsibility. This stack compounds with scale: more assets mean better forecasting, lower penalties, and stronger unit economics while capital requirements of tens of millions in exchange collateral filter out the rest. The market consolidates toward few winners.[5]
- **On the network side, the opportunity concentrates at DSOs.** Four TSOs with strong in-house build capability contrast with ~870 DSOs that have limited visibility below the substation.[6] The validated wedge is planning; the structural gap is transparency; and the next value layer is location-aware execution. The strongest products sell measurable network outcome, e.g. more hosting capacity from existing assets, deferred reinforcement, lower losses, or shorter outages, not generic digitalization.
- **Grid cybersecurity expands beyond utilities to renewable portfolios and equipment manufacturers.** The strongest startup wedge is distributed energy fleet security posture management: non-disruptive asset and firmware visibility that can expand into compliance, secure access and response. The moat is energy-specific device intelligence and auditable workflows rather than a generic dashboard, and high-risk OT actions still require human approval.
- Network operators are regulated monopolies that buy through formal procurement processes and planned budget cycles. A first contract can take six to 36 months, and missing the relevant budget window can delay a purchase until the next cycle. Industrial sites, retailers, fleets and IPPs buy against their own P&L and can move faster when the economic case is clear. Founders should therefore identify the economic buyer, budget owner and procurement path for their specific customer archetype. Pricing should be tied to a value case the customer can justify today, and sales cycles should not be based on an average across the energy market.

Building in one of these spaces? We want to hear from you - contact details at the end of this paper.

How we researched this. This thesis is based on more than 25 structured reference calls conducted between May and July 2026 with transmission and distribution system operators, utilities, corporate venture capital investors, and founders across the DACH region and Benelux-alongside a proprietary mapping of ~90 European grid startups. Public data is cited in numbered footnotes; the data cutoff is 3 August 2026. Two exceptions apply: BNetzA's MiSpeL determination of 1 October 2026 and its smart-meter rollout survey of 21 September 2026 are included despite falling after the data cutoff, because they materially change the rules for storage and bidirectional charging (Part IV) and the metering baseline (Part II).

Portfolio highlights: companies from the HTGF and Vireo portfolios are marked in the text like this.

PART I

The Framework

The grid, not generation, is the bottleneck

E.ON CEO Leonhard Birnbaum has described grid capacity as a central constraint on the energy transition.[7]

For twenty years, the energy transition was a generation story: build renewables, drive down their cost, scale. That phase succeeded and its success created a new problem. The infrastructure that moves, balances, and protects electricity was built for a handful of large, dispatchable plants feeding power one way, still complex but compared to todays' requirements, fairly easy to manage. Running that system was never simple, but the problem was bounded: few sources, forecastable output, and control that sat with the operator. It now has to absorb millions of decentralized, weather-dependent, bidirectional sources. Three megatrends make this the defining infrastructure challenge of the next decade:

Megatrend 1: Renewables won on cost but made the system volatile

Fraunhofer ISE's 2024 German analysis estimates levelized costs of €41–69/MWh for ground-mounted solar and €43–92/MWh for onshore wind, compared with €109–181/MWh for a new CCGT. The ranges support a clear cost advantage for most new renewable projects; falling equipment costs support further build-out, while financing, permitting and grid access still shape deployment.[8]

But cheap power does not arrive in a steady stream. Germany recorded 573 hours of negative wholesale prices in 2025, up from 457 in 2024.[9] Negative prices indicate periods of surplus or inflexibility, but they are also shaped by subsidy design, inflexible generation, congestion and cross-border conditions. The direction continued into 2026: EU-wide negative-price hours doubled year on year in the first quarter, and 17% of German hours in April cleared below zero.[10] The UK's system operator projects flexibility needs of 55 GW by 2030.[11] Structural consequence: volatility is becoming a persistent market feature and a potential revenue source for assets able to respond at the right time and location.

Megatrend 2: Electrification raises demand materially

Electricity covers roughly a quarter of German final energy consumption today. In the current second draft of the Network Development Plan, 2045 net electricity consumption ranges from 869 to 1,195 TWh and gross consumption from 989 to 1,294 TWh, depending on the electrification scenario. Three drivers account for most of that increase: electric vehicles, from 2.4 million in 2024 to 37–45 million by 2045; heat pumps, from 2.0 million to 11–14 million; and hydrogen electrolysis, from 0.2 GW to 32–70 GW, which at 116–241 TWh is the single largest new load in the scenarios. The transmission operators note that EV and heat pump uptake is currently running behind the political targets these scenarios assume. Demand therefore rises materially, but it does not double in every scenario.[12] Millions of rooftop PV systems, batteries, heat pumps and EVs also make distribution flows more bidirectional. Structural consequence: operators need better metering, monitoring and intelligence, although the maturity of those layers varies by voltage level and operator.

Megatrend 3: Energy sovereignty – the primary resource is sovereign; the system around it is not

Sun and wind cannot be embargoed or priced by a cartel, so the fuel is sovereign. The hardware is not: Europe trades a recurring dependency on imported fuel for a dependency on imported equipment, and it differs by technology. Solar and batteries are a manufacturing concentration, with China holding about 85% of solar and 80% of lithium-ion battery supply-chain production capacity. Wind is a materials concentration: European firms lead turbine assembly, but over 90% of EU permanent magnets come from China. Grid infrastructure is a capacity problem rather than a geopolitical one, with European-made high-voltage transformers running lead times of two years or more. Germany's revised BSIG responds on the security side: the interior ministry can ban a component from critical infrastructure where the supplier is judged a risk, and defines by regulation which components fall under that power. **Structural consequence:** as the grid digitalizes, buyers place more value on auditable supply chains and operational technology security.

One bottleneck, one question

Three megatrends, three structural consequences and all of them converge on the same asset: a grid that must be expanded, digitalized, and made flexible simultaneously, at a pace it has never operated at. That much is consensus; you can read it in any consulting report. What a consulting report will not tell you is where a venture-scale company can be built. So this paper is organized around a single question:

Which grid problems will be solved by venture-backed startups – and which will be solved by incumbents, infrastructure capital, or politics?

In this paper, different grid segments are tested against a three-part **venture filter**:

- **Reality.** Is the pain real, quantified, and paid for today or does it depend on a regulation or rollout that has not happened yet?
- **Access.** Who is the buyer, what is their procurement logic, and how long is the path to first revenue?
- **Capture.** Can a startup capture venture-scale returns or does the value accrue to incumbents, asset owners, or the regulated monopoly?

A segment that does not pass the first test is not yet a venture opportunity. One that does not pass the second is still investable, but slow enough that the entry price should reflect it. One that does not pass the third is not a venture case at all, whoever solves it. Each chapter ends in a verdict, and some of those verdicts are a clear no. Where a claim rests on a proposed rule, a company announcement, or our own judgement rather than an enacted fact, we say so.

What we deliberately leave out

The following are real levers for relieving the grid. We exclude them not because they are unimportant, but because they are better solved outside venture capital, and we say why.

TOPIC	WHY OUTSIDE THE VENTURE LENS	WHAT WOULD CHANGE OUR MIND
Bidding-zone reform (price zones)	Splitting Germany's single price zone would relieve the grid, but it is politically blocked as it would cause higher prices in the south. This is clearly a political lever, thus out of scope for VCs.	An actual zonal-split decision which would re-price every flexibility business in Part IV. Upside, not a threat.
Grid hardware & synthetic inertia (grid-forming inverters, STATCOMs, sub-second buffering)	A real and growing need as synchronous generation retires, e.g. the UK already procures grid-forming inverter services at scale. But capex-intensive, with infrastructure-style return profiles. Out of scope for early-stage VC.	Asset-light models on top of the hardware layer, e.g. software-defined inertia dispatch.
Long-duration energy storage (LDES)	A real long-term system need. Germany has opened a general long-term generation-capacity auction in which qualifying storage may participate, but auction economics, technical qualification and project-finance risk remain material. Asset ownership remains a poor fit for most early-stage VC.	The first 4.5 GW auction opened in July 2026 with a 15-year obligation period. It is not a dedicated LDES auction. Qualifying storage can participate subject to demanding technical rules, and the notice recorded outstanding approval steps. A repeatable financing market with proven auction economics would strengthen the venture case.[13]
Generation-side assets	A different market, extensively covered elsewhere. This paper's core claim is precisely that the bottleneck has moved from generation to grid.	–
Hydrogen and molecule-side flexibility	A separate value chain and infrastructure debate.	–

The map: how we structure the space

Grid investing is typically structured around technology categories like hardware, software, storage, but the boundaries dissolve in practice: a virtual power plant is both flexibility and software; a smart meter is both hardware and enabler. We structure the space by **value stream and buyer** instead:

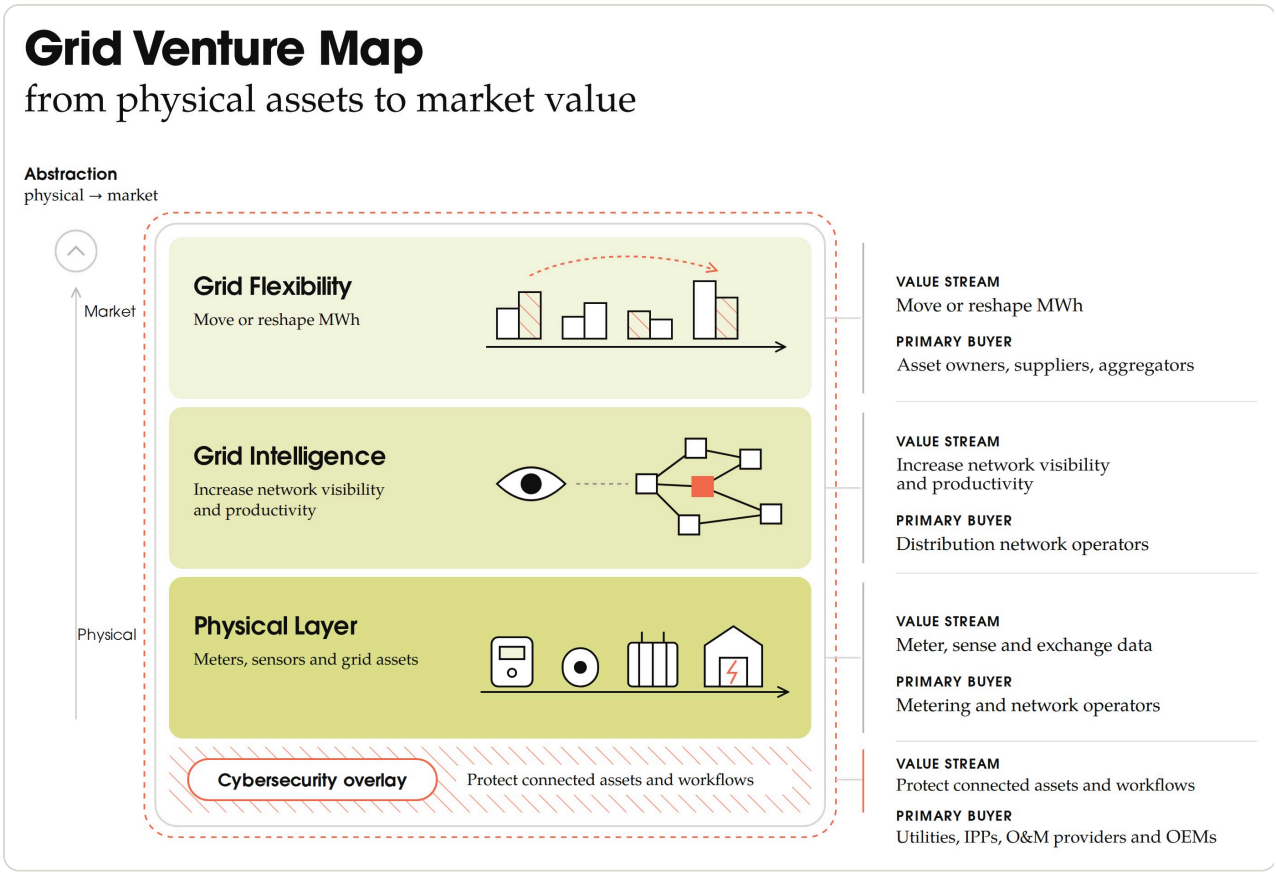


Figure 1. The grid venture map by value stream and buyer.

In the following, we dive into the Physical Layer in Part II, Grid Intelligence in Part III, Grid Flexibility in Part IV, Grid Cybersecurity in Part V and we close the deep dive in Part VI with a GTM playbook based on the operational lessons from our reference calls.

PART II

Physical Layer

What the Grid Must Have Before It Can Be Intelligent or Flexible

The physical layer is the foundation of both grid flexibility and intelligence; without it, neither can perform at the scale and reliability the energy transition requires. Three components define it: (1) the metering infrastructure that enables residential flexibility and dynamic pricing; (2) the sensing layer that makes grid assets observable; and (3) the planning and permitting toolchain that governs the pace of physical grid expansion. In each case, the hardware itself carries an infrastructure-capital return profile. The venture opportunity sits one layer up: in the software, data products, and workflow automation that the physical infrastructure enables.

The gate: Smart Meters & the Metering Gap

WHY NOW Metering is the first gate, not the whole market. Granular consumption data is the precondition for residential flexibility, V2G, dynamic tariffs, and VPP settlement (detailed in Part IV) – but a meter alone does not make a device controllable, accessible to an aggregator, or commercially contracted. Standardized data access, controllable-device frameworks, aggregator access, and customer contracts are subsequent gates, each of which can fail independently.

Smart meters covered 5.9% of all German metering points at 30 June 2026. For mandatory cases in the 6,000–100,000 kWh group, 26.1% were equipped in the first half of 2026.[14] The first figure should not be compared directly with an EU average that uses a different denominator. German law targeted 20% of mandatory cases by end-2025 and 90% by 2032.[15] Since March 2026, the Bundesnetzagentur has opened proceedings against 434 operators that missed the 20% quota, 77 of which had not started the rollout at all.[16] ACER separately identifies smart-meter, data, and market-access barriers as compounding constraints across EU markets, with 59% of EU consumers still on flat-price or regulated contracts.[17] Cross-country penetration comparisons are unreliable: published datasets define smart meters differently, and the Commission's July 2026 trajectory targets remain proposals. Where the rollout is owned, it moves - E.ON became the first German operator past one million installed smart meters in March 2026. The gap is a structural grid-control problem for DSOs and TSOs, not merely a product-distribution delay. It is also specifically a residential and small-commercial gap: in Germany, sites above 100,000 kWh per year, above 30 kW peak load, or on a medium-voltage connection already carry mandatory interval metering with 15-minute data sent to the grid operator, which is why the industrial and commercial opportunities in Part IV do not wait on the rollout.

CASE IN POINT Companies dependent on granular consumption data have stopped waiting. Octopus and Reshape install their own meters, operating at 1-5-minute resolution. Where the rollout has not arrived, building-level submetering fills the gap: Metiundo (Vireo) offers multi-commodity metering for property owners, covering electricity, gas, heat and water in one data layer.

ENTRY GAP Not the meter itself. Metering hardware and gateway administration are regulated, contested, and margin-thin, and several large platforms already occupy the downstream analytics layer. The opportunity is at the application layer the rollout progressively unlocks – but founders must show a revenue path that works at today's ~5% penetration in Germany and a credible plan for the subsequent gates: standardized data access, device control, and market access.

VERDICT Smart-meter rollout is a binding constraint and a reliable leading indicator, but not a sufficient condition for product adoption. Invest at the unlock, not at the meter. MiSpeL makes the meter gate tighter for residential and small commercial sites, where storage and bidirectional-charging revenue needs quarter-hourly metering, usually a smart meter. Larger C&I sites already have interval metering, so the rollout pace matters less for them.

Making grids observable: Substation Sensors & Grid-Edge Monitoring

WHY NOW As detailed later in Part III, most substations remain unmonitored and asset condition is assessed reactively. The physical sensing layer that makes observability possible is the precondition for everything the intelligence layer builds on top and it is largely absent below the substation.

CASE IN POINT The sensing stack splits into three tiers that answer different questions. Asset condition, at the substation and on the line: OKTO, EcoPhi, Heimdall Power and Greenwood Power instrument individual assets for real-time monitoring and predictive maintenance. Corridor inspection, above the network: LiveEO (DTCF) is the most scaled European player in drone and satellite-based inspection of power infrastructure, with Beagle, HyLight, Hepta Insights and Voliro active at earlier stages. Low-voltage observability, behind the substation: secondary substations and the feeders below them are largely uninstrumented, and BentoNet supplies gateway and sensor packages that measure bidirectional flows in local distribution stations.

ENTRY GAP Drone and satellite monitoring is the most commercially active sub-segment. The thinner layer is low-voltage observability, where DSOs are blind on the side of the network that the smart-meter rollout has not yet reached either.

VERDICT Physical observability is the precondition for digital intelligence. The investment case is not in the sensor; it is in the interpretation layer the sensor enables.

Grid Permitting & Planning Acceleration

WHY NOW A new 380 kV line takes seven to ten years to build, roughly seven of them planning and approval. Capital is not the binding constraint on grid expansion; planning capacity is. Both the EU Grid Action Plan and Germany's Netzausbaubeschleunigungsgesetz explicitly target this bottleneck directly. The cost of not fixing it is visible in the system: German congestion management cost €3.1 billion in 2025, against €187 million a decade ago, because power cannot move to where it is needed.

CASE IN POINT The category is underserved relative to the pressure bearing down on it. Qualified engineers and planners are not keeping pace with the build-out; reference calls with TSO operators confirmed that intelligent planning and optimization software can save billions in unnecessary

reinforcement and delayed commissioning. Gilytics (HTGF) operates directly in this space: a GIS-based route planning and optimization platform for power lines and linear infrastructure spun out of ETH Zürich.

ENTRY GAP Software that embeds into permitting workflows – routing, environmental assessment, stakeholder coordination, schedule management – carries switching costs that compound with every project delivered.

VERDICT Permitting acceleration software is worth more than the software that operates the finished asset and the regulatory pressure that creates that value is only intensifying.

Part II – five takeaways

- Across meters, sensors and permitting tools, the investable layer lies in the software and data products sitting one step above the physical infrastructure.
- Smart meters are a gate, not a market. Founders must show a revenue path that works at today's 5.9% German penetration before betting on the rollout catching up.
- The sensing layer that makes substations and lines observable is largely absent below the high-voltage level and is the precondition for everything the intelligence layer builds on top.
- Permitting and planning delays, not capital availability alone, are increasingly constraining grid expansion. Software that shortens planning and approval timelines can create substantial value for network operators by bringing capacity online sooner, reducing delay and engineering costs, and deferring or avoiding reinforcement expenditure. Although a startup captures only a fraction of this system-level value, the resulting customer ROI can support meaningful willingness to pay and the regulatory pressure behind the problem is intensifying.
- The best founders are not waiting for the infrastructure to arrive. Octopus installs its own meters and Gilytics embeds into permitting workflows as they run today, building a business on the gap rather than on its closing.

PART III

Grid Intelligence

The network side: SEE, DECIDE, ACT

The grid is not only limited in its hardware set-up. It is also short of visibility, planning capacity and controllable operating intelligence.

As millions of decentralized assets connect to the system, network operators must answer three operational questions:

- **SEE:** What is connected, what is happening, and where are the constraints?
- **DECIDE:** What should be built, scheduled, connected or forecasted?
- **ACT:** What can be controlled safely, and what action improves the network outcome?

These three jobs define the grid intelligence stack. They are not technology categories, but operating tasks that network operators must perform as the system becomes more distributed, bidirectional and volatile. AI is the connective layer across the stack: it turns fragmented sensor and asset data into forecasts, links those forecasts to planning and operational decisions, and enables safe, increasingly automated action. Its value emerges at the intersection of visibility, decision-making and control.

The investment opportunity lies in software that improves a measurable network outcome, such as additional hosting capacity, deferred reinforcement, lower losses, shorter outages, faster connection processing or more accurate procurement.

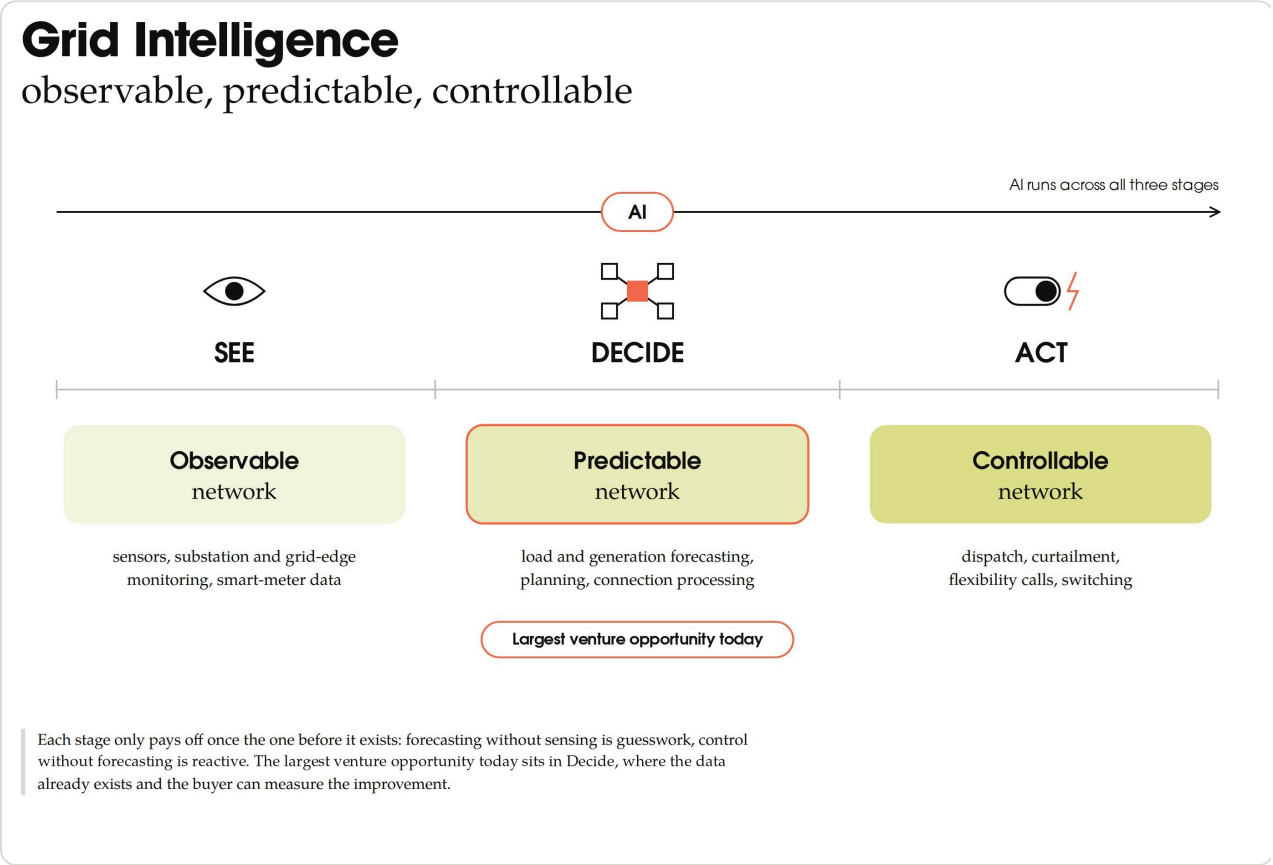


Figure 2. Grid intelligence: from an observable to a predictable to a controllable network.

The buyer matters as much as the product. Germany has four transmission system operators and roughly 870 distribution system operators. TSOs generally have deeper internal software capabilities, stronger data sovereignty requirements and a greater tendency to build critical systems themselves. DSOs are more fragmented, more unevenly digitized and more exposed to the operational consequences of distributed generation, heat pumps, batteries and electric vehicles. Our interviewees described limited real-time visibility below many substations, fragmented legacy systems, partly manual documentation and forecasting models under pressure from new load and generation patterns. [18] For venture backed companies, the DSO layer is therefore the more open entry point.[19]

Know your buyer: four TSOs, ~870 DSOs, one gap

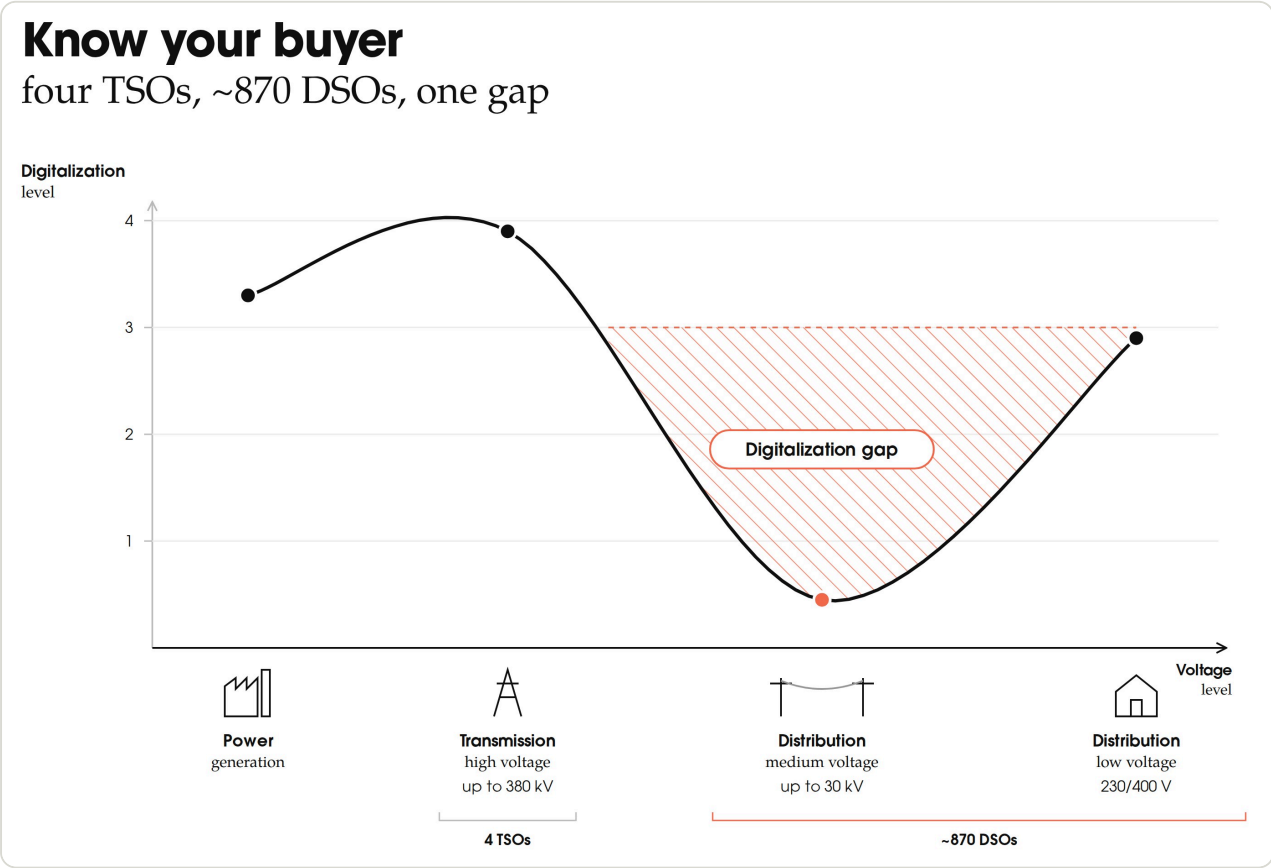


Figure 3. Know your buyer: the digitalization gap in the energy grid.

This does not mean that every DSO software product is investable. Across SEE, DECIDE and ACT, the same screening question applies: does the product become embedded in an operator's workflow, data model and operating decisions, or does it remain a replaceable feature?

The strongest positions combine four elements:

- access to proprietary or hard to replicate data
- integration into an operational workflow
- measurable improvement in a network outcome
- switching costs that increase with every project, asset or decision processed

The chapter follows the operator's three jobs. We start with **SEE**, because better decisions and safer actions depend on a consolidated and operationally useful view of the network.

SEE – grid transparency and data

WHY NOW A typical large DSO operates around 200 legacy systems with no consolidated view, and historical load profiles that have stopped working as millions of variable inputs replace a handful of predictable plants. The problem is not a lack of data but a lack of the ability to use it. Digital twins are one useful product form, but cross-system data harmonization is the deeper and more open gap. Products should be assessed against the workflow and measurable network outcome they improve.

CASE IN POINT Envelio (former HTGF portfolio company) entered DSOs through one acute, quantifiable pain point: automating grid connection requests, a workflow that had grown from hundreds to thousands per year and expanded from that wedge into grid planning and operations, today serving 100+ utilities and expanding into the US. It has also been majority-owned by E.ON since 2021: validation of the market, and a reminder that exit paths here may run through utilities.[20] Others active in this space include Plexigrid and Withthegrid.

ENTRY GAP The gap is the layer that sits across systems: data harmonization at DSO scale, and monitoring below the substation where the grid still lacks instrumentation.

VERDICT The most commercially validated segment in grid intelligence, now consolidating. New entrants need either the cross-system data layer or a sharper wedge and not a better twin. One boundary worth stating clearly: connection software can reduce processing time, improve application quality, and make queues more transparent, but it cannot by itself remove delays caused by missing physical capacity, permitting, supply-chain constraints, or third parties.

DECIDE – planning and forecasting

WHY NOW Interviewees reported that forecast errors can create material procurement losses and weaker network planning, in some cases reaching millions of euros for a utility.[21] The error grows with every heat pump and rooftop panel added to the grid. The investable claim is not that forecasting must be a standalone product; it is that load, generation, and flexibility forecasts can be sold against a measurable improvement in procurement or planning performance. AI-based forecasting is graduating from a feature inside planning tools to a product in its own right.

CASE IN POINT enercast (HTGF) has provided renewable energy forecasting for TSOs, DSOs, and traders since 2012. Gridraven sits at the intersection of forecasting and capacity optimization through hyper-local weather AI for Dynamic Line Rating. On the asset management and investment planning side, Utiligize is active with a solid customer base. The question for new entrants is whether the category is still open or already consolidating around these positions.

ENTRY GAP The DSO tier remains the clearest forecasting opportunity because internal capability is lowest and the data gap widest. Forecasting can improve both energy procurement and network planning. An adjacent and growing category is connection-request intelligence: battery queues at TSO level are now in the hundreds of GW, and the shift away from first-come-first-served allocation turns automated connection assessment from a convenience into a compliance requirement. The defensible metrics here are staff hours per application, hosting-capacity utilization, speculative capacity removed, and the ability to design and manage flexible connections and not a promise to create physical capacity.

VERDICT Forecasting remains one of the clearest near-term network products because ROI is measurable and proof cycles can be shorter. Connection-request software is attractive when it proves administrative productivity and better capacity allocation, while being explicit about the physical and regulatory delays it cannot control.

ACT – operations, automation, and the execution layer

WHY NOW Substations are important sources of network data, and interviewees described gaps in monitoring, asset-condition data and remote operation at parts of the distribution grid.[22] Protection systems already clear faults automatically in milliseconds; the issue is not replacing manual fault response. The opportunity is better observability, coordinated control, asset management and operator decision support. ENTSO-E's blackout recommendations reinforce the need for protection review, ride-through performance and better TSO-DSO data exchange.[23]

CASE IN POINT EcoPhi is developing an AI-enabled merging unit that digitizes measurement data and consolidates selected measurement functions, with a product thesis centered on lower-cost data acquisition, monitoring, and condition insight at substations. Zaphiro integrates phasor measurement with existing SCADA systems without interrupting workflows. On Dynamic Line Rating, Sentrisense (acquired by Megger) validates the market for line-level sensing, with the acquisition by an established grid instrumentation incumbent confirming the strategic value of the category.

ENTRY GAP Substation intelligence is a focused early-stage bet with a proven commercial model and a hard forcing function. The larger open category is the DSO-side coordination layer that ingests VPP and battery dispatch signals and acts in near real time. It must be location-aware, so a nationally useful price response does not worsen a local feeder constraint. MiSpeL creates price-led flexibility at low voltage without a locational signal. The reported start of dynamic grid fees for storage (2030 at the earliest) leaves a gap. That raises the urgency of the DSO coordination layer.

VERDICT The emerging frontier of grid intelligence. Higher technical and trust barriers than SEE or DECIDE and correspondingly stronger positions for those who clear them.

AI in the control room – where it fits, where it fails

AI runs across SEE, DECIDE, and ACT but its constraints are sharpest in the execution layer, which is why it is addressed here rather than as a separate peer section.

WHY NOW Grid operations present a specific AI constraint that most software markets do not: faults cascade in seconds, and a confidently wrong output can contribute to an outage. The near-term opportunity is therefore not autonomous control but supervised decision support: pattern detection, load and generation forecasting, document processing, and staff-light workflows such as voice support for understaffed DSOs. Interviewees cited each of these as real operational needs. [24]

CASE IN POINT No scaled European player has yet established a position in AI-native grid operations intelligence. The EU's AI.grids program supports the development of sovereign European tools in this space, and the July 2026 AI Omnibus moved Annex III high-risk obligations for relevant critical-infrastructure use cases to December 2027[25], creating a defined window before compliance requirements tighten.

ENTRY GAP The near-term product is a supervised copilot embedded in DSO workflows: simulation-tested, fully logged, with bounded authority and human approval for consequential actions. Knowledge graphs aligned with IEC 61970 CIM improve traceability and constraint checking are useful for auditability, though they do not certify safety or remove model error. The longer-run bet is broader operational

automation, which requires certification, a validation case an accountable operator can defend, and a trust relationship that takes years to build.

VERDICT Knowledge graphs and explainability improve the evidence chain; they do not prove safety. The investable near-term opportunity is a supervised, simulation-tested and fully logged operator copilot. Broader autonomous control requires bounded authority, human-in-the-loop approval and a validation case that an accountable operator can defend.

Part III – six takeaways

- The venture path runs through DSOs: TSOs rather build in-house, impose data-sovereignty and auditability conditions, and appear to be rather closed to startups as primary customers.
- Vertical integration is the VC screening criterion: switching costs, data rights, and embedded business logic determine whether a position is defensible and not feature breadth.
- SEE is validated and consolidating; the open gaps are the cross-system data layer and sub-substation visibility, not another planning point solution.
- DECIDE, particularly standalone forecasting sold against measurable procurement or planning improvement, is the clearest near-term opportunity with quantifiable ROI and shorter proof cycles.
- ACT is the next value layer: substation intelligence is the proven early bet; the DSO-side dispatch coordination layer is the most structurally important open gap in the chapter.
- AI in grid operations means supervised copilots now and bounded autonomy later; zero-error tolerance makes the governance bar as high as the technical one.

PART IV

Grid Flexibility

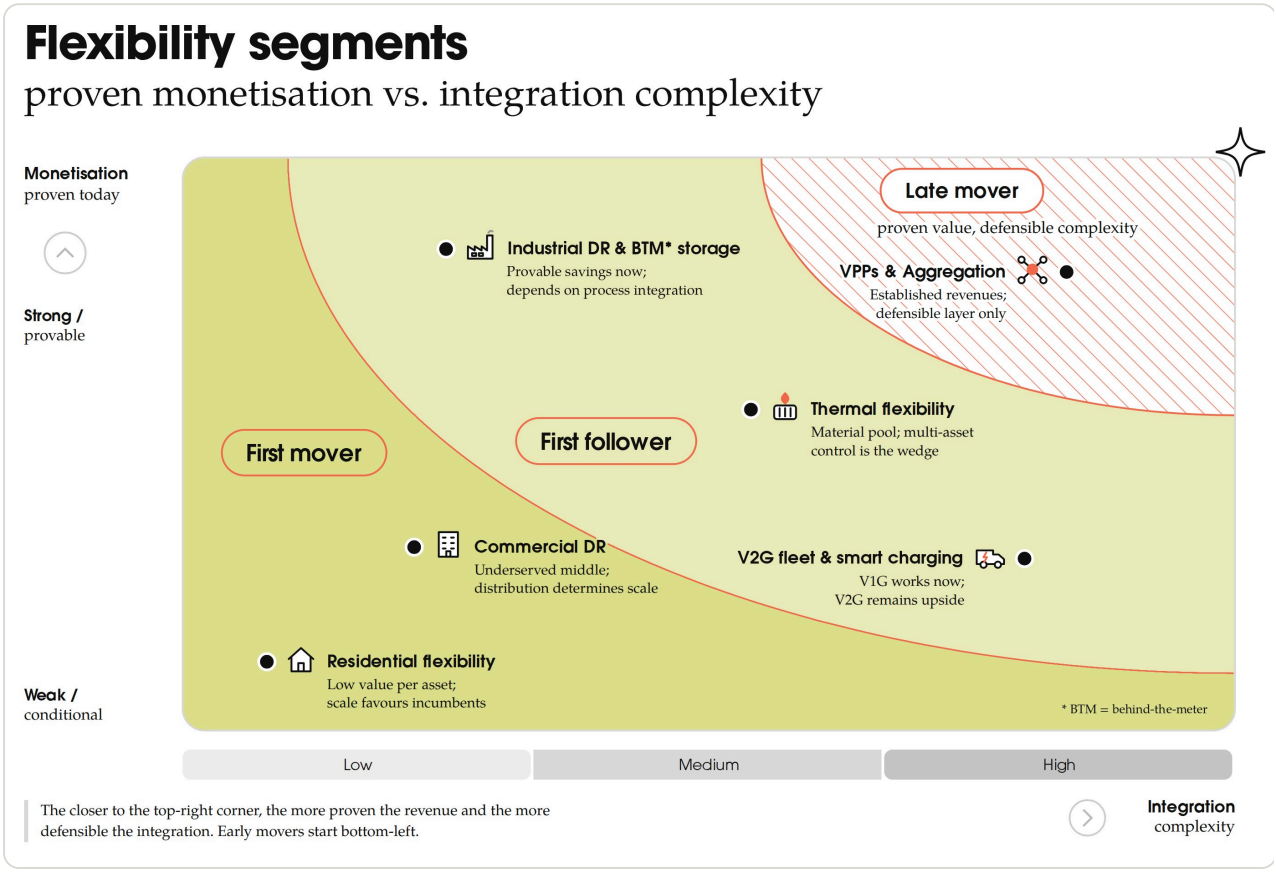


Figure 4. Flexibility segments: proven monetisation vs. integration complexity.

The market side: who gets paid for absorbing volatility?

Electricity must be balanced continuously, which makes missing flexibility costly. Germany curtailed about 9.4 TWh of renewable generation in both 2024 and 2025,[26] negative wholesale prices reached 573 hours in 2025,[27] and 17% of German hours in April 2026 cleared below zero.[28] Other European markets also recorded hundreds of negative-price hours in 2025.[29]

Cheap power is a system signal, not a local permission to consume. A flexible asset can improve the national supply-demand balance while worsening congestion on the feeder behind which it sits. Uniform price-led automation can also synchronize flexible loads and create new peaks. The valuable coordination layer therefore optimizes against both market prices and local network constraints.

Where flexibility already earns real money is the TSO ancillary services stack (FCR, aFRR, and mFRR) alongside spot and balancing markets. Dynamic-tariff adoption remains limited.[30] Each business case should specify the revenue streams it can stack and the obligations each one creates.

This chapter covers six segments in descending order of near-term conviction: (1) Industrial DR and Behind-the-Meter Storage, (2) Commercial DR, (3) Thermal Flexibility, (4) Residential Flexibility, (5) V2G Fleet Flexibility & Smart Charging, and (6) VPPs & Aggregation.

Industrial DR & Behind-the-Meter Storage – highest conviction, hardest integration

WHY NOW Daily price amplitudes of €200/MWh reward anyone who can shift load, and the savings math is provable at the site level today without any regulatory change. §19 StromNEV, which grants large consumers network-fee reductions of up to 90% for constant or atypical load, remains the structural obstacle[31] , but BNetzA's May 2026 AgNes concept keeps existing baseload relief through 2031 and postpones the future industrial design to 2027. [32] Flexibility-friendly reform is a potential upside, not an adopted baseline. Industry consumes 41% of German electricity.[33] The strongest load-shifting candidates have thermal or temporal inertia: refrigeration and cold chains, food processing, aluminum and metals, and data centers. Under MiSpeL, behind-the-meter batteries keep EEG support and levy relief for the eligible share while combining PV, grid charging and market-driven feed-in, which widens the revenue stack for optimization and Energy-as-a-Service models.

CASE IN POINT The segment divides into three models: process-demand-response software, which optimizes existing industrial loads against market signals; battery optimization software, which manages peak shaving, arbitrage and ancillary-service revenues; and Energy-as-a-Service providers, which finance, install and operate C&I batteries. Encentive (Vireo) represents the first model, Furo the second, and FION Energy (HTGF) and Scale Energy (Vireo) the third.

ENTRY GAP The remaining whitespace is narrower than “industrial flexibility” generally. It is vertical-specific process-flexibility software that models production constraints, optimizes load against market signals, and manages settlement or billing, particularly for industrial sites whose flexibility cannot be captured through a standard battery-led solution. This should be treated as a market hypothesis rather than an established gap, given the expanding overlap between process optimization, battery optimization and Energy-as-a-Service offerings. For data centers, a sharper wedge is flexible-connection modelling plus enforceable dispatch rather than a generic demand-response platform.

VERDICT The clearest near-term flexibility opportunity in this chapter. A handful of industrial customers can build a real business because each site is large and the savings math is provable today. What is genuinely hard is process integration, which rewards deep domain expertise. Network-fee reform may improve economics further, but its timing and design are uncertain. In data centers specifically, faster or cheaper grid connection matter more than recurring demand-response revenue.

Commercial demand response – the underserved middle

WHY NOW Commercial buildings consume 26% of German electricity[34] across roughly two million heated non-residential buildings.[35] Their owners now need to manage PV self-consumption, electrification, peak avoidance and external grid signals. The recast EPBD, the EU law setting minimum energy requirements for buildings, adds a regulatory wedge: building-automation and control requirements already cover technically and economically feasible non-residential systems above 290 kW and extend to systems above 70 kW by the end of 2029.[36] The smart meter gateway rollout is beginning to reach

commercial metering points, and dynamic tariff availability is expanding, together creating the price signal infrastructure that makes automated load response commercially viable for the first time at this scale. The rule creates more instrumented buildings; it does not solve fragmented BMS estates or monetization.

CASE IN POINT Portfolio owners like real estate operators, retail chains, logistics companies offer one commercial relationship across many buildings, making aggregation economics far more attractive than residential. Reshape Energy (Vireo) addresses this through an M&A rollup of building energy service companies, acquiring and integrating businesses across the value chain to offer property portfolio owners a single point of contact from energy assessment through financing, implementation, and ongoing optimization. Trawa approaches the same customer from the procurement side: a full-stack energy management and procurement platform for commercial customers that handles market access, load optimization, and billing without requiring an in-house trading function, removing the energy expertise barrier that keeps most SMEs on fixed tariffs and out of flexibility markets entirely.

ENTRY GAP Cross-BMS integration, portfolio-level control, telemetry and market settlement. Portfolio owners can provide one commercial relationship across many sites. Building-automation rules increase the number of instrumented systems, but technical control, interoperability and market participation still have to be proven. The repeatable integration playbook across major BMS vendors and building archetypes is the product; the portfolio-level sales motion is the go-to-market. Early proof that energy and flexibility savings survive metering, integration, and service costs is the bar to clear.

VERDICT A regulation-supported but integration-heavy middle segment. Less volume-hungry than residential, less process-complex than industrial, but the distribution question is the hardest part: who already owns the building-portfolio relationship determines who wins.

Thermal flexibility – a material but fragmented pool

WHY NOW Heat is a physical battery that already exists at scale. Hot-water tanks, large heat pumps, electric boilers, district heating networks and the thermal mass of buildings themselves can all shift electricity demand across time, and as heating electrifies this pool grows structurally. The resource splits by where the heat sits: (1) residential, where heat pumps, water heating and storage devices fall under §14a EnWG, real but thin-margin and increasingly bundled by incumbents; (2) commercial and industrial on premise, where building-portfolio optimization is commercially active today; and (3) district networks, where large heat pumps, electric boilers, thermal storage, CHP and waste heat represent the largest single opportunity and the least built software layer. The gap across all three is not infrastructure technology, which the European Commission's Joint Research Centre finds broadly mature at component level, but integration and control across hybrid thermal networks.

CASE IN POINT Green Fusion (Vireo) operates at the building-portfolio tier, optimizing heating systems across residential housing stock. Viboo (HTGF) applies predictive heating control to unlock flexibility from the thermal inertia of buildings, without relying only on additional storage or heat-pump capacity. At district scale, the physical assets are arriving: Berlin is building a 75 MW wastewater heat pump and Hanover started a 30 MW project in 2026.[37] The coordination software layer is thinner but not empty: Gradyent already sells real-time digital-twin optimization to district-heating operators, so new entrants need a sharper wedge than a generic twin.

ENTRY GAP Teams that pair heating-system domain knowledge with power-market access and can co-optimize heat demand, large heat pumps, thermal storage, CHP and waste heat. Economics should work on operational savings, with flexibility revenue as additional value, and municipal-utility procurement must be credible.

VERDICT The venture opportunity here lies in system integration software, not in owning district-heating infrastructure. Building-portfolio optimization is validated; multi-asset district control is less mature and less consolidated, though not empty (Gradyent operates at district scale), and requires a realistic route through municipal utilities.

Residential flexibility – a volume game the incumbents are winning

WHY NOW Households consume 29% of German electricity and increasingly combine grid demand with heat pumps, rooftop PV and batteries.[38] Residential aggregation often benefits from large portfolios because forecasting, trading and customer acquisition have fixed costs.

CASE IN POINT The market already includes scaled platforms such as Rabot Energy (HTGF), Kraken, Tibber, 1KOMMA5°, Enpal and Sonnen. A new entrant must therefore show a specific segment, distribution advantage or infrastructure role rather than assume a horizontal platform can displace incumbents.

ENTRY GAP The opportunity is not to build another residential platform but to move faster than incumbents into the spaces regulation opens. §14a, which made time-variable grid fees available from April 2025, and the mandatory dynamic tariff obligation under §14a EnWG create brief windows where the product layer has not yet been built out. The same logic applies to balancing-market access for small assets as aggregation thresholds fall. A startup that moves into one of these windows early or that builds infrastructure the incumbents need to comply has a more defensible position than one trying to out-acquire or out-brand Tibber or 1KOMMA5°. MiSpeL is a current example: its simplified Pauschaloption (PV up to 30 kWp, one meter) still awaits state-aid approval, and operators have until 30 September 2027 to implement it. Metering, allocation and billing tools for home storage and bidirectional wallboxes will be needed during that transition.

VERDICT Crowded at the platform level; investable only at the edges where regulation opens new mechanics faster than incumbents move. High bar.

V2G & Fleet Electrification – start where the batteries already stand still

> "With a fleet, every car connected, perhaps a buffer battery, this is a money-making machine. But business cases crash if the grid is not there."
>
> **Martin Wienands, Venture Partner, Encevo**

WHY NOW EVs contain substantial battery capacity and often remain parked for long periods. An authors' estimate puts total installed battery capacity in Germany's BEV fleet above 100 GWh, but only a

small and changing share is simultaneously connected, available and V2G-capable.[39] Germany removed double grid fees on EV feed-in from January 2026. On 1 October 2026, BNetzA adopted its MiSpeL determination, which for the first time treats bidirectional charging points largely like stationary storage. Operators can mix renewable and grid electricity, charge at low prices and feed back at high prices without losing EEG support for the renewable share. Grid electricity that is stored and fed back is netted against grid consumption, reducing levies and network charges. A transition period runs until 30 September 2027, during which application requires the consent of the grid and metering operator.[40]

CASE IN POINT The market splits into three lanes that behave differently. Residential is closing: V2G is arriving as closed OEM bundles, and consumer smart charging is already crowded with at-scale incumbents like ev.energy, Kraken and Tibber. Commercial depot fleets are the natural entry point: vans, buses and company vehicles return to an owned site, park predictably overnight, run standardized hardware, and sit under a single contract covering hundreds of batteries at once. The fragmentation that makes residential V2G hard does not exist in the same way here, though cross-OEM vehicle-charger constraints, DSO acceptance processes and OEM control over approved hardware remain real. Long-haul is a different business: charging happens mid-route at public corridor sites during rest breaks, so there is little parked battery to monetize, and the binding constraint is the megawatt grid connection rather than the scheduling software. The IEA counted only 22 V2G-capable models in May 2026, less than 1.5% of available EV models, a reminder that the technology stack is still maturing.

ENTRY GAP The startup openings are what the OEM bundles do not cover, and they differ by lane. In depot fleets: charging optimization, scheduling that models battery degradation, and integration across manufacturers' closed systems. Several companies sit here: FLEXECHARGE (Vireo) with grid-aware smart charging software for chargers and backend providers, and Pionix (Vireo) with an open-source OCPP stack monetized through enterprise services. IO Dynamics (HTGF) is already operating at depot scale with IO-ELON: manufacturer-independent, integrating dynamic tariffs and solar forecasts into charging schedules, and demonstrating peak load reductions of around 36% at real logistics depots. It earns on smart charging today, with grid services as the natural next step. Delta Charge (Vireo) covers the physical side of the same wedge: turnkey depot charging hubs with integrated battery storage, delivered as a service so fleet operators electrify without financing the infrastructure themselves. Depotcharge (HTGF) adds the commercial layer: it runs a manufacturer-independent marketplace on which haulers monetize idle depot charging points by opening them to other e-truck fleets, a revenue stream that needs no V2G discharge.

In long-haul the opening is not flexibility but power delivery. AFIR requires truck charging pools of 3,600 kW every 60 km on the TEN-T core network by 2030, and the MCS standard runs to 3.75 MW, so battery-buffered hubs that let a corridor site deliver megawatt power without waiting years for a grid upgrade matter more than any scheduling layer. That is the connection constraint from Part III reappearing as a charging problem.

VERDICT Fleets are the clearest first customer because depot parking and a single buyer simplify contracting and operations, not because the technology is solved. Any business model here needs to work on smart charging / vehicle to grid (V2G) revenue alone, with discharge revenue as genuine upside rather than a base-case assumption. Degradation-aware scheduling and cross-OEM integration are the technical differentiators that will separate durable companies from those that get squeezed out as the OEM bundles expand.

MiSpeL removes the main regulatory blocker for discharge revenue in Germany, but not the operational one: it requires quarter-hourly metering, and smart-meter coverage stands at 5.9% of metering points (30 June 2026). The base case should therefore still rely on smart-charging revenue, with MiSpeL-enabled discharge as upside that becomes more bankable after the transition period.

VPPs & aggregation – the bundling layer is the moat

WHY NOW Small assets can already participate in spot markets through market participants or aggregators, and spot orders can be submitted in 0.1 MW increments. Balancing products use a 1 MW minimum offer size and permit aggregation.[41] The aggregator's role is to combine assets, forecast availability, manage dispatch and settlement, and carry or contract for balance responsibility. The question is no longer whether VPPs work, but who owns which layer and how defensibly.

CASE IN POINT "VPP" is a buzzword masking five distinct layers: (1) asset connectivity, (2) forecasting, (3) aggregation, (4) market access and dispatch optimization, (5) settlement. Most startups do one well and stitch the rest. The honest evaluation question is not "do you do VPP" but "which layer are you genuinely strong at and which do you buy or fudge?" At scale the segment is crowded and commoditizing: Next Kraftwerke (former HTGF, acquired by Shell) is best understood as a market-facing VPP operator, aggregator and power trader. Octopus/Kraken are full-stack platforms with retail licenses and balance responsibility; the hardest and most capital-intensive position to replicate. NOMOS is a newer attempt at this position in residential: it holds a German retail licence and balance responsibility, runs most operations in-house, and sells under OEM and installer brands, while connectivity comes largely from partners. trawa focuses on customer-side energy management, combining energy procurement, consumption monitoring and intelligent control of flexible assets—such as batteries, charging infrastructure, cooling systems and CHP units—with market participation depending on the commercial setup. Qurrent connects energy resources through an IoT gateway, validates and prequalifies them for relevant markets, and optimizes their operation, positioning it primarily as an asset-integration and VPP-orchestration layer rather than a full market-access or BRP platform. The optimisers have moved up the stack. enspired, Entrix and Suena trade with their own market access, contract directly with large battery owners, and increasingly underwrite floors and tolls, what they leave to aggregators is connecting small assets and the end-customer relationship behind them. Capalo AI goes furthest in the Nordics, bundling pre-qualification, trading and balance-responsibility service into one route-to-market offer. terralayr inverts the model: it owns batteries and runs a virtualisation platform on which several of these optimisers trade slices of the same asset at once. Exchange access alone requires collateral, bank guarantees, and trading licenses that take years to assemble, raising the entry threshold for anyone trying to compete at the full-stack level.[42]

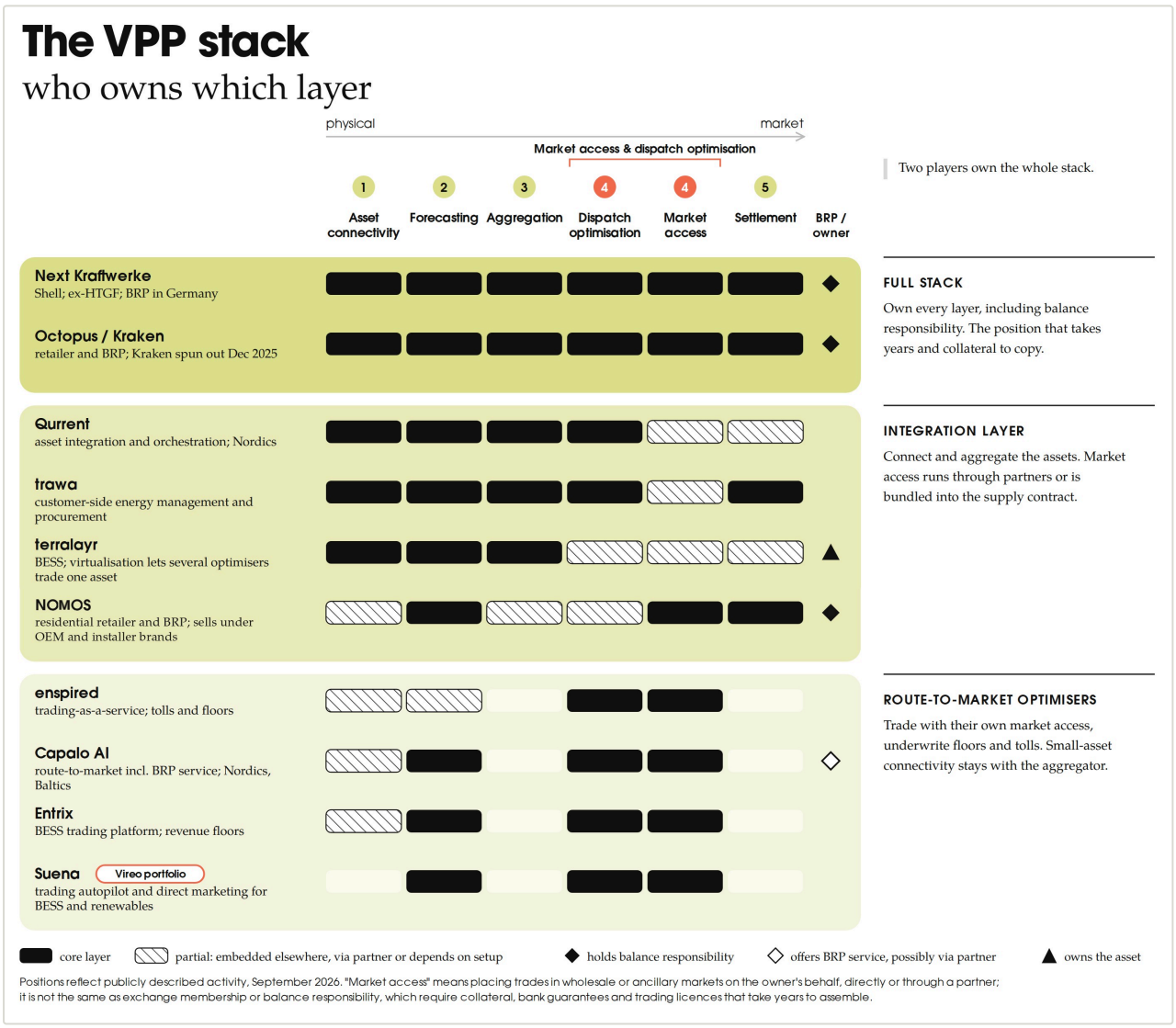


Figure 5. The VPP stack: who owns which layer.

ENTRY GAP Three openings. First, a genuinely differentiated layer, for example, the DSO-facing coordination of VPP dispatch, where the product optimizes against local grid constraints rather than wholesale markets alone, is treated separately in the grid intelligence section (Part III) as a network-side product. Second, new asset classes the incumbents have not wired up: V2G fleets, industrial processes, district heat. The generic horizontal VPP platform is an execution race with compressing margins, the wrong race to enter now at this stage.

Third, the enablement route: selling the flexibility operations stack to energy companies themselves. Retailers lose margin on C&I customers that install batteries, solar and heat pumps but sit on traditionally priced contracts, and they cannot retain those customers without flexibility products they are rarely equipped to operate. A platform that lets the energy company keep brand, customer and trading while running onboarding, multi-asset optimization and settlement underneath converts one retailer contract into hundreds of sites. The trade-off is concentrated platform risk: few large buyers, long sales cycles, and the retailer's option to build in-house at scale.

VERDICT Attractive only with a defensible layer or a new asset class. The bundling infrastructure itself – connectivity, forecasting, balance responsibility – is where structural defensibility lives, and it consolidates toward few winners.

Part IV – five takeaways

- Short-term flexibility is an execution problem, not a technology problem: the venture opportunity is the software and aggregation layer that makes existing business models work at scale.
- Industrial and commercial DR carry the highest near-term conviction, but German network-fee reform is a potential upside pending a 2027 design decision, not part of the base case.
- Thermal flexibility and fleet charging remain underpriced pools. The thermal wedge is multi-asset control; the fleet wedge should work on V1G while V2G interoperability remains constrained.
- The residential and VPP layers are largely spoken for and the edges and new asset classes are where the venture opportunity lives.
- B2B fleets are the right entry point for V2G, but the business model must work without discharge revenue.

PART V

Cybersecurity

Cybersecurity map

from operational core to governance

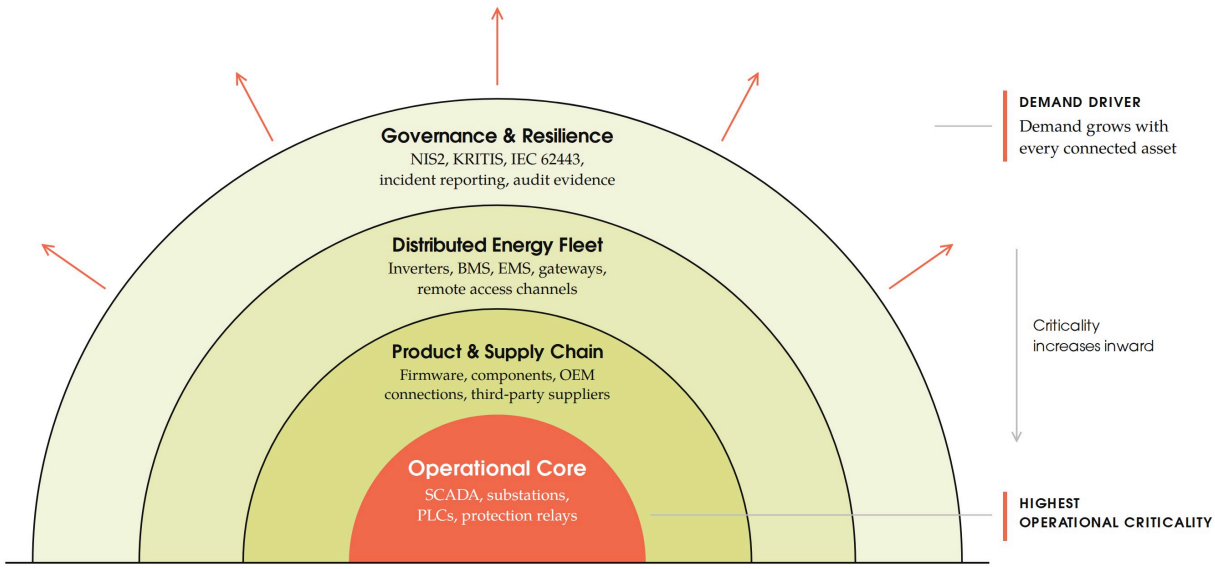


Figure 6. Cybersecurity map: from operational core to governance.

Securing a grid built from connected assets

Every smart meter, inverter, battery controller, EV charger, substation controller and dispatch interface adds digital control to a physical system. Cybersecurity is therefore an overarching layer and demand for it grows with every connected asset the other chapters add.

The buyer base has widened beyond grid operators to include IPPs, renewable O&M providers, storage operators, aggregators, charging-point operators, district-heat operators and equipment manufacturers. The EU electricity Network Code on Cybersecurity applies risk-management rules to high-impact and critical-impact entities[43]; the broader buyer thesis rests on NIS2, the Cyber Resilience Act (CRA), contractual requirements and operational risk.

The investment question is therefore not whether security spending will grow. It is which products can enter without disrupting operations, show useful evidence quickly and expand from a narrow wedge into a wider operational platform.

One fact shapes every product decision in this market: OT is not IT. Operational technology prioritizes availability, integrity and safety. Assets often remain in service for 15 to 25 years. Reboots and patches can interrupt physical processes, and shutdown windows are limited. Delivery models – edge appliances, agentless SaaS, managed SOC – sit across all four layers below and should be chosen as an entry point, then expanded without requiring full redeployment. Generic IT tooling often produces too many alerts, lacks asset context and assumes that software can be updated immediately.

We organize the following section around operational core (layer 1), product and supply-chain security (layer 2), distributed energy fleet security (layer 3) and governance and resilience (layer 4).

The operational core – securing control systems and substations

WHY NOW The operational core comprises the systems that directly monitor and control physical processes: SCADA systems, protection relays, RTUs, PLCs, substation controllers and the networks connecting them. The primary buyers are grid operators, utilities, large generators and industrial asset owners. Attackers can now cause physical and commercial damage: malicious commands, lost visibility, blocked remote access or manipulated setpoints can stop production, interfere with curtailment instructions and disrupt balancing or PPA obligations. State-linked activity and industrial ransomware continue to target operational environments.[44]

CASE IN POINT Passive traffic monitoring can identify unexpected commands, unusual device communications and lateral movement. Detection alone is becoming difficult to defend as a venture category because established vendors already cover large accounts: Rhebo combines passive OT network monitoring with anomaly and intrusion detection for energy grids and is the most credible German-native player in this space. Claroty, Nozomi Networks, and Dragos set the international benchmark at large accounts, the category's consolidation is itself instructive: Nozomi was acquired by Mitsubishi Electric (~$1B, completed January 2026) and Armis is being acquired by ServiceNow ($7.75B, announced December 2025).

ENTRY GAP Utilities increasingly depend on OEM engineers, subcontractors and technicians who need temporary access to critical equipment. Secure OT access is a well-funded category in the USA — Cyolo, Xona and Xage have all raised significant rounds for it — but their public positioning targets large industrial accounts. For a European start-up, the open question is whether it can reach a comparable volume and deal size. The underserved slice is vendor-neutral access for smaller operators with rotating external users: task-specific permissions, session recording, identity controls and rapid revocation, at a price and deployment effort smaller operators can absorb. Enterprise zero-trust tools do not fit rotating contractors or legacy OT protocols.

VERDICT Secure access remains a credible mid-market wedge. Monitoring is investable only when it converts alerts into actions an operator can safely approve or reaches assets that incumbent deployment models cannot serve.

Product and supply-chain security – from component to site

WHY NOW This layer concerns the software, firmware, third-party components and suppliers embedded in meters, chargers, inverters, gateways, protection devices and other connected products. The primary

buyers are OEM product-security teams, integrators and asset owners responsible for long-lived equipment. The key challenge is lifecycle responsibility: manufacturers must understand what is inside each product version, respond to vulnerabilities and provide secure updates, while asset owners need to know whether a product weakness reaches an operationally critical site.

CASE IN POINT Product-security players are split between horizontal tools and energy-specific niches. ONEKEY automates SBOM generation, firmware analysis and vulnerability management for IoT and OT manufacturers, and Test of Things (Helsinki) turns CRA and IEC 62443 requirements into automated tests and continuous compliance monitoring. Both are largely horizontal and compete in a crowded layer. PHYSEC (Bochum, spun out of Ruhr-University's Horst Görtz Institute) is more energy-specific, combining cyber and physical protection for energy and water meters and sensors in the field. The energy-specific gap is linking a component vulnerability to affected product versions, installed sites, responsible suppliers and feasible remediation windows, because a vulnerability only matters operationally once the operator knows where the affected equipment is deployed.

ENTRY GAP The product-to-site system of record should link manufacturers, O&M providers, firmware versions, remote connections, open vulnerabilities, contractual responsibilities and remediation status. This is more valuable than a static supplier questionnaire because it shows how a weakness travels through the supply chain and reaches a live asset. NIS2, the electricity-specific cybersecurity framework and the Cyber Resilience Act provide regulatory pressure, but the durable value lies in maintaining an accurate operational and commercial evidence chain.

VERDICT The category is structurally attractive but crowded at the horizontal product-security level. The investable wedge is product-to-site traceability for energy equipment, not SBOM generation alone. OEMs may offer a more direct initial buyer than utilities, but product qualification, integration requirements and long support cycles can create substantial sales friction. The strongest companies will connect product-security evidence to installed-base intelligence and actionable remediation.

Distributed energy fleet security – the fastest-emerging category

WHY NOW Distributed energy fleet security sits between full OT monitoring and compliance software. Three forces converged on it in the past 18 months: NIS2 enforcement is live with audit deadlines, compliance certification is becoming a condition of grants and financing, and the first coordinated state attacks on renewable fleets have landed, most visibly on more than 30 wind and solar farms in Poland in December 2025. Behind them sits a structural tailwind: AI-driven electricity demand is accelerating buildout across the sector. The buyer is an IPP, storage operator or O&M provider managing many geographically dispersed sites. The fleets are heterogeneous systems: expensive crown jewels such as inverters, which can cost hundreds of thousands of euros, sit alongside cheap devices such as CCTV cameras that often connect directly to the public internet. The protected assets include inverters, plant controllers, BMS and EMS systems, gateways, weather stations, remote-access channels and manufacturer cloud connections. Complexity is compounded by fragmented, outsourced fleet management: a European IPP may combine country-level offices, third-party SCADA integrators and OEM teams visiting the same plant. The first problem is often visibility, increasingly required for reporting obligations, rather than threat detection. Operators rarely have inverter-level visibility into their inventory: a current record of every connected device, firmware version, owner, remote connection and end-of-life date across the portfolio. The gap is becoming more urgent with the Cyber Resilience Act and the EU's move to restrict financing for

projects using high-risk inverter vendors. Without that baseline, vulnerability prioritization, patch planning and audit evidence remain manual. In our reference calls, operators described the same progression: first a reliable, always-current picture of every device and firmware version across the fleet, then the ability to act on it — prioritized remediation, audit-ready compliance evidence, controlled vendor access — and eventually recovery capability and availability intelligence from the same data. The commercial logic points to recurring per-site or per-portfolio pricing rather than one-off assessments, and toward a common security baseline an owner can impose on every new plant it acquires or builds.

CASE IN POINT Uno Security and Centrii show the category moving from on-site appliances toward cloud-delivered, energy-specific platforms. According to the company, Uno Security provides portfolio-wide device and firmware visibility over existing remote connections, without on-site hardware, and adds AI-assisted prioritization with human-approved remediation. Centrii describes itself as an energy-infrastructure cybersecurity platform delivered as SaaS. Both contrast with appliance-based approaches. Whether remote-only discovery delivers sufficient depth and remains safe across heterogeneous OT fleets still has to be proven at scale.

ENTRY GAP A useful product should combine six capabilities: continuously maintaining an inventory of connected assets; tracking firmware and lifecycle status; monitoring cloud and third-party connections; mapping network topology and segmentation against the expected zone model; prioritizing vulnerabilities according to their operational and financial impact; and translating the resulting evidence into plant-level, portfolio-level and compliance views. These capabilities cover posture management; detection and response, where the product actively protects the plant rather than preparing it for an audit, is the natural second act. It must also be quick to deploy and operate without disrupting live assets. Discovery must be provably safe on fragile OT devices: active probing on industrial networks has historically crashed controllers, which is precisely why passive appliances became the default, and why non-disruptive remote discovery is the hard technical problem in this category rather than a convenience feature. Hardware-heavy solutions, however, are difficult to justify across the long tail of smaller plants. The category's history offers a warning: earlier OT anomaly-detection tools often failed commercially because findings were hard to act on, deployments and sales cycles were long, and CISOs struggled to secure plant managers' buy-in. Mapping proprietary protocols and device fingerprints was another costly hurdle that AI tools could have made much easier.

VERDICT Distributed fleet security posture management is one of the strongest venture wedges in the chapter. It has a clear buyer, a deployment gap left by appliance-based incumbents and a route from inventory into vulnerability management, compliance, remote access and incident response. The moat must come from energy-device intelligence, deployment data and workflow integration and ultimately from becoming the compliance system of record for the portfolio. The same wedge extends beyond energy: data centers, water treatment and EV-charging fleets entered scope under NIS2 without having been covered by its predecessor, so the distributed-fleet playbook can travel across critical infrastructure. Energy-device intelligence remains the deepest near-term moat, and out-of-band anomaly detection based on energy readings can serve as an added layer of validation.

Governance and resilience – compliance as the entry product

WHY NOW Operators must translate technical reality into incident notifications, management reports, risk registers, audit trails and remediation plans. NIS2 requires an early warning within 24 hours, a fuller

notification within 72 hours and a final report within one month; Germany's implementation has been in force since 6 December 2025.[45] The KRITIS umbrella law, in force from 17 March 2026, adds physical protection and resilience duties for critical facilities.[46] The opportunity is not a separate tool for every law but one evidence layer that maps assets, controls and incidents across NIS2, the electricity NCCS, CRA, KRITIS and IEC 62443.

CASE IN POINT The horizontal GRC market has responded to NIS2 with a wave of compliance automation tools. Kertos automates evidence collection, risk assessment and documentation across GDPR, NIS2, DORA and the EU AI Act, compressing time-to-audit-readiness from months to days. DataGuard and Secfix address the DACH mid-market with similar multi-framework coverage. These are credible tools for IT governance, but none is built for energy OT: they treat NIS2 as a documentation and process problem rather than an operational one, and they have no native understanding of inverter firmware, substation topology, curtailment obligations or the asset-level evidence that energy auditors and insurers actually require.

ENTRY GAP Buying triggers are widening beyond regulation. Investor due diligence and insurance requirements increasingly demand security evidence, which can shorten IPP sales cycles that compliance deadlines alone would not. The KRITIS umbrella law adds physical protection and resilience duties for critical facilities, so physical and cyber risk now converge on the same sites. Spine Security covers the physical side with multi-sensor towers and on-site AI that provide perimeter security across portfolios of unmanned sites, including substations. The software opportunity is the workflow that links physical observations and cyber evidence to one risk and reporting process.

VERDICT Compliance automation remains a strong entry point for smaller utilities and operators. The larger platform opportunity is continuous evidence management tied to live assets. Pure document generation will be easy to copy.

The delivery model decides who can buy

Three delivery models recur across the four layers. Edge appliances provide deep traffic visibility but increase installation and maintenance work. Agentless or low-touch SaaS can reach a larger number of small sites but may see less of the network. Managed SOC services add expertise and 24/7 coverage but can make margins and scalability more service-heavy. The strongest companies use the delivery model as an entry choice, then expand functionality without requiring a complete redeployment.

SOC should therefore be treated as a delivery model, not a standalone product category. The venture question is whether software increases analyst leverage and standardizes deployment across customers. AI-assisted automation can support that leverage only when actions remain explainable, permissioned and auditable.

The buyer determines the first wedge

- DSOs and municipal utilities. The fastest wedge may be compliance evidence, secure external access or affordable monitoring that does not require a large internal SOC.

- IPPs, BESS operators and O&M providers. The first wedge is more likely to be portfolio asset visibility, firmware and vulnerability posture, manufacturer-cloud monitoring and business-aware risk prioritization.
- OEMs and integrators. The first wedge is CRA readiness, product-to-site traceability and long-term firmware support.
- Large utilities and TSOs. They already buy from established OT-security vendors and often operate internal security teams.

The venture view

The most attractive categories differ by buyer. For renewable operators, distributed fleet posture management is the clearest gap. For smaller utilities, compliance evidence and secure access remain strong. For OEMs, CRA-driven product security is real but competes with horizontal tooling. Physics-aware detection and automated response have high technical value, but they also face the highest trust, validation and incumbent barriers.

The central screening question is whether the product can move from visibility to action without losing safety. A company that only inventories assets risks becoming a feature. A company that can use proprietary device context to prioritize risk, guide remediation, prove controls and coordinate human-approved response can become a durable operating layer.

Part V – five takeaways

- Security demand grows with every connected grid and energy asset. The customer base now includes renewable operators and equipment manufacturers, not only utilities.
- OT is not IT. Availability, safety, long asset lives and limited shutdown windows make non-disruptive deployment and operational context essential.
- The fastest-emerging category is distributed energy fleet security posture management. It starts with asset and firmware visibility, then expands into compliance, access and response.
- Grid cybersecurity is evolving from focused, low-friction wedges to broader, energy-specific platforms. Agentless asset discovery, continuous inventory, misconfiguration detection, and AI-assisted prioritization can enable portfolio-wide deployment while linking cyber exposure to operational and financial risk. Human oversight remains essential when actions could affect OT environments.
- The venture moat is not a dashboard or a generic AI agent. It is energy-specific device intelligence, trusted deployment, auditable workflows and the ability to convert cyber evidence into safe operational action.

PART VI

The Grid Go-to-Market Playbook

Selling into the grid: what we learned from those who did

The energy grid is one of the most consequential markets a founder can build in and one of the least forgiving of generic go-to-market thinking. This guide distills what we have learned from operators, founders, and investors who have navigated it, into a practical framework for early-stage companies entering the space.[47]

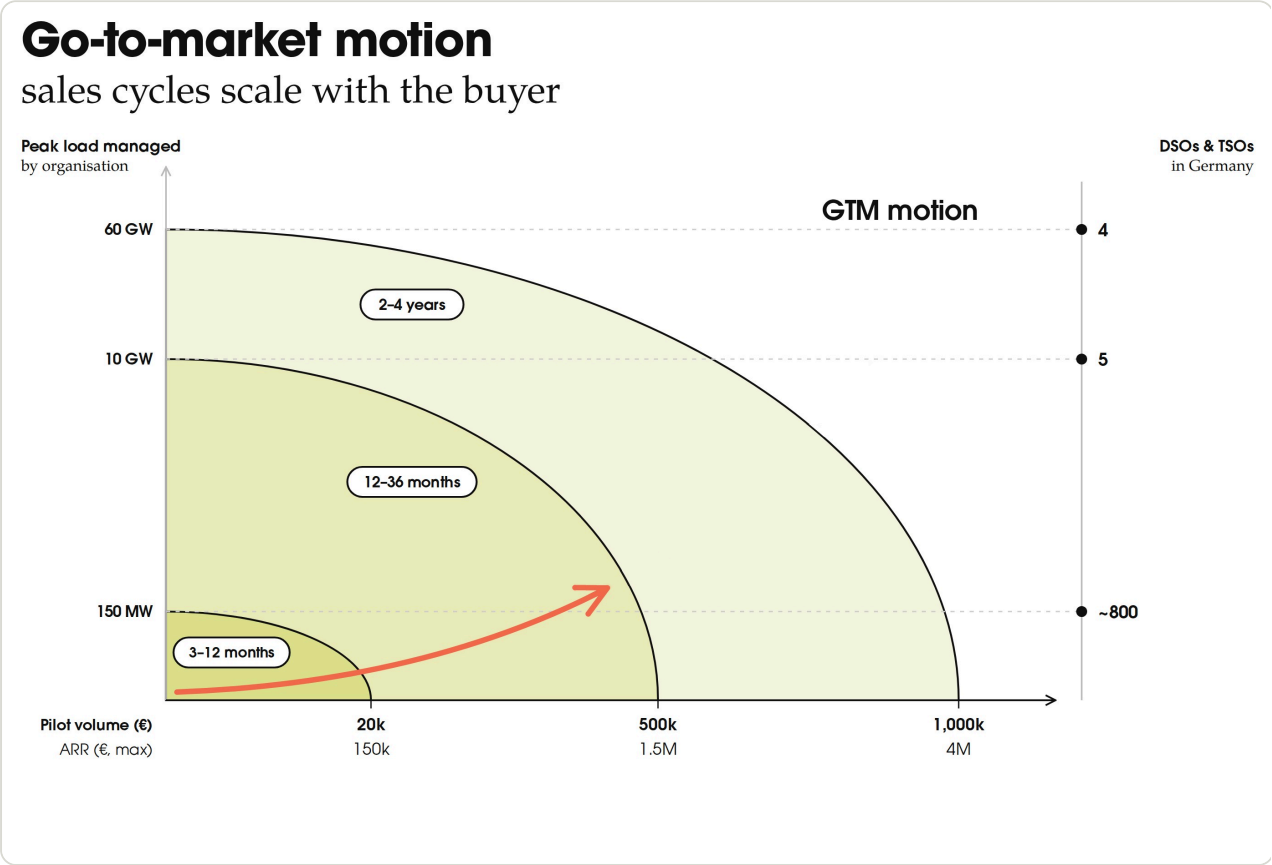


Figure 7. Go-to-market motion: sales cycles scale with the buyer.

1. Know Your Market Before You Enter

The energy grid is not a single market. It is a stack of distinct customer archetypes, each with its own procurement logic, budget cycle, and pain profile. Before approaching your first customer, you must understand who you are actually selling to. In Germany alone, there are approximately 870 distribution system operators (DSOs), four transmission system operators (TSOs), and a long tail of municipal utilities (Stadtwerke). Selling to a small DSO like Stadtwerke Bielefeld (150 MW peak load, ~220k connection points) is a fundamentally different exercise than selling to a large DSO (10–14 GW, 7 million customers) or

TenneT (60–80 GW, operating at the transmission level only). The decision-maker, the budget cycle, the required certifications, and the sales timeline all change with customer size. Conflating these archetypes is one of the most common early mistakes grid founders make.

Understand the Customer's Economic Logic First. The single most important insight for any grid founder is this: grid operators do not think like normal enterprise software buyers. DSOs and TSOs operate as regulated natural monopolies with guaranteed returns on capital expenditure (CAPEX) – this means they earn a fixed, regulator-approved return on every transformer, cable, and substation they deploy. This has critical consequences. First, enhanced operational efficiency is not a primary incentive: a DSO does not lose customers if its service quality is mediocre, and it does not gain revenue by reducing congestion. Thus, under today's regulation, CAPEX pricing almost always outperforms OPEX or SaaS pricing in this market. Even if your product is pure software, structuring it as a one-time license with annual support will dramatically reduce procurement friction. EcoPhi and Inframind both arrived at this conclusion independently: utilities prefer to activate a budget line they already have rather than justify a new recurring cost to their regulator. The framing implication follows directly: a software product that saves €200k per year in operational costs is a harder sell than the same product presented as a €500k capital investment with a defined asset life and a predictable return profile. This conclusion depends on today's regulation: if the AgNes reform changes how operating costs are remunerated or applies efficiency targets more evenly, the case for capex-style pricing weakens and subscription models become more viable.

Enter Through the Non-Critical Layer. The proven entry strategy for grid software and hardware startups is to begin with a highly specific, non-mission-critical use case and prove measurable value before expanding into the core systems over time. Envelio's entry point was the grid connection request process: a painful, manual, high-volume workflow that had ballooned from hundreds to thousands of requests per year as renewable installations surged. It was not the control room. It was not real-time grid management. It was a back-office process that operators were desperate to automate and winning there gave Envelio the trust and the data access to move deeper into the stack. The principle generalizes: data harmonization, asset documentation, connection request management, and reporting automation are all legitimate wedges into a customer that would never let an unknown startup touch its SCADA system on day one.

Regulatory Entry Points and how to use them. Regulation is the most powerful external forcing function in the grid market, and a well-timed regulatory tailwind can compress a sales cycle significantly. The SF6 ban, the NIS2 cybersecurity directive, the smart meter rollout mandate, and the BNetzA's tightening efficiency targets for DSOs are all creating genuine urgency in specific pockets of the market. However, regulatory pressure only converts into sales pipeline if non-compliance carries real consequences, e.g. through financial penalties, loss of operating license, or public accountability. Founders should map the regulatory calendar carefully: identify which mandates have hard deadlines and enforcement teeth, and which are aspirational targets that operators can safely ignore for years. The former are GTM opportunities; the latter are noise.

The Cross-Industry Entry Path. "For hardware and OT software startups, one underrated entry strategy is to prove product-market fit in an adjacent industry first and then move into the grid. Grid operators are risk-averse. Without references, a startup will struggle to land a pilot. But one with a live customer in industrial automation, water or manufacturing enters the conversation with a completely different level of credibility," says Dr. Niklas Rotering.

2. The Sales Reality

What makes grid sales genuinely hard is not the process but the context: long procurement cycles, deeply siloed organizations, and a customer structurally insulated from competitive pressure. Founders who underestimate this dynamic burn runway on deals that were never going to close in the timeframe they modelled.

Segment Your Playbook. There is no universal grid sales playbook. Build a distinct sales motion for each customer archetype you target, and resist the temptation to pursue large customers too early. The mid-sized DSO tier, approximately 70–100 operators in Germany with 100k–500k customers, is the most strategically attractive entry segment: large enough for a meaningful pilot budget (€100k–500k), small enough for an accessible decision-maker, and replicable enough to build a standardized sales motion. For smaller DSOs and Stadtwerke especially, lead with insight rather than a product demo: a regulatory briefing or benchmark against peer operators positions you as a trusted advisor before you are ever a vendor. Know which game you are playing before you enter the room.

Network Is Not a Nice-to-Have, It Is the Product. In the grid market, who you know determines whether you get a meeting, not just whether you close a deal. Almost every founding team that achieved meaningful DSO traction within months of incorporation came out of a leading electrical engineering institute like RWTH Aachen, ETH Zürich, or TU Munich and leveraged alumni networks, research partnerships, and institute relationships to get their foot in the door. For founders without this background, the path is longer but not closed: industry events, VDE committees, BDEW working groups, and Committees all provide structured access to the right people though building enough trust to win a first pilot through cold outreach alone will typically take two to three years. This is especially true for regional and locally-operated customers like smaller DSOs and Stadtwerke, where personal rapport and on-site presence matter as much as the product itself: plan for a field-heavy sales model, and factor the runway implications into your planning from day one.

Direct Sales First, Indirect Sales for the Long Tail. Keep sales founder-led until you have a repeatable playbook: your technical credibility and ability to navigate a complex organization are the product as much as the software or hardware. As the customer base grows, system integrators, consultants, and utility partners become valuable channels for the long tail of smaller operators too numerous to cover directly. Hardware-software hybrid companies have an additional lever: the hardware installation creates a natural on-site relationship that can be used to introduce and expand the software layer, a pattern EcoPhi has used effectively with its substation digitization platform.

3. The Sales Cycle: What to Expect

The grid sales cycle is long and founders who have not experienced it before consistently underestimate by how much. This is not a market where a compelling demo converts to a signed contract in six weeks. The combination of regulated procurement processes, internal change management, integration complexity, and institutional risk-aversion means that even a well-positioned startup with the right product and the right contact should budget 6 to 36 months from first meeting to signed pilot depending on customer size.

Design Your Pilot to Convert. A well-designed pilot has three non-negotiable elements: a clear success metric agreed upfront, a defined timeline, and a named internal champion who has skin in the outcome. Envelio's pilot with a large German distribution system operator worked because the use case – automating grid connection requests – had a

measurable output (processing time, error rate) that both sides could evaluate objectively. Where possible, pilots should be paid: a customer who has committed budget is motivated to make it work.

Integration and Consulting Costs Are a Hidden Sales Drag. One of the most underappreciated friction points in grid sales is the integration and consulting burden that comes with every new customer. Legacy IT landscapes at DSOs and utilities are deeply fragmented: Inframind counted approximately 200 separate software systems at a typical large DSO, many of them custom-built and poorly documented. Connecting a new product to this environment requires significant professional services work, which is expensive, time-consuming, and hard to standardize. This prevents many grid software startups from building a clean, repeatable sales playbook: every new customer feels like a custom project. The mitigation is to invest early in pre-built connectors for the most common systems (SAP, standard SCADA platforms, GIS tools) and to outsource integration and change management to specialist partners rather than building that capability in-house.

The Lock-In Upside: Once In, You Stay In. Grid customers are exceptionally sticky once won: churn is close to zero for products embedded in operational workflows, and customer lifetimes are often measured in decades. This changes the unit economics calculus significantly: a high customer acquisition cost is justified by that long lifetime. Prioritize getting in over optimizing the initial contract value. A small first deal that embeds you deeply is worth far more than a large deal that keeps you at arm's length.

4. How to Close: Procurement Logic and Timing

Understand the Procurement Cycle. DSOs and utilities run on annual CAPEX budget cycles, typically set in Q3 or Q4 for the following year. A deal that misses the budget cycle does not slip by a quarter, it slips by a full year. Founders should aim to have a signed pilot agreement or at minimum a Memorandum of Understanding before the customer's budget freeze, which in practice means starting the commercial conversation three to six months earlier than feels necessary. For larger customers with multi-year investment planning horizons, the timeline extends further: getting onto a utility's investment roadmap requires being in conversation at the planning stage, not the procurement stage.

Be Part of the Regulatory Process – Selectively. Several interviewees identified participation in regulatory working groups and industry committees (Ausschüsse) as a meaningful lever for both closing deals and shaping the market conditions that create future pipeline. Being present in BNetzA working groups, BDEW committees, or VDE technical panels positions a startup as a credible market participant rather than an outside vendor, and creates informal relationships with potential customers and regulators simultaneously. The caveat is equally important: committee work is time-intensive and the return is slow. Founders should be highly selective: they should choose one or two bodies directly relevant to their product area and commit consistently, rather than spreading thin across many.

5. How to Scale: Land, Expand, and Navigate Fragmentation

Winning a first customer in the grid market is hard. Scaling beyond it is a different kind of hard. The structural features that make this market attractive – regulated returns, long customer lifetimes, high switching costs – are the same features that make it slow, fragmented, and resistant to the kind of rapid replication that drives VC-scale growth in other sectors. Founders who scale successfully in this market do so by being deliberate about sequencing: which customer segment to anchor in, which reference to build first, and when to expand geographically.

The Anchor Customer Is Everything. In a market built on trust and reputation, a single high-quality reference customer is worth more than ten mediocre pilots. The anchor customer — ideally a well-known, mid-to-large DSO or a nationally recognized utility — serves as social proof for every subsequent conversation. Choose the anchor deliberately: it should be large enough to be recognized by peers, but not so large that the procurement process consumes years of runway. Be willing to invest disproportionately in winning it – the downstream value of that reference justifies the short-term margin sacrifice.

Germany's Fragmentation Is a Feature, Not Just a Bug. With approximately 870 DSOs in Germany, the market is deeply fragmented and this is both the central scaling challenge and an underappreciated opportunity. The challenge: no single customer represents more than a small fraction of the addressable market, which means scaling requires winning many customers with a standardized playbook rather than a handful of large accounts. The opportunity: the long tail of small and mid-sized DSOs is largely underserved by incumbent software vendors, who focus on the largest operators. A startup with a well-packaged, easy-to-deploy product can move through this segment faster than the fragmentation figure suggests — particularly if it can leverage indirect channels, system integrators, and a strong anchor reference to generate inbound interest. The key is to resist over-customizing for each new customer: standardization is the only path to the unit economics that make this market viable at VC scale.

When to Transition from Founder-Led Sales. Hire your first dedicated salesperson not when you have too many deals to manage, but when you have a repeatable playbook someone else can execute — meaning at least two or three customers closed through a consistent process, a clear ICP you can brief a new hire on, and a handle on the typical objections. Grid customers expect technical credibility and domain depth in early conversations; staying founder-led preserves that. After the playbook is proven, staying founder-led becomes the bottleneck.

6. Internationalization: Sequence Deliberately

Internationalization in the energy grid market is technically straightforward and commercially complex. The underlying engineering requirements for grid software and hardware are largely identical across the EU. Voltage levels, grid physics, and core operational workflows do not change at the border. What changes is everything around the product: the regulatory framework, the procurement culture, the language of the customer relationship, and most importantly the network. Expanding internationally without a local network is not slower than expanding with one; it is a different activity entirely.

Start with Austria, Then Sequence from There. The most consistent internationalization advice across reference calls points to Austria as the natural first step beyond Germany. The regulatory framework is closely aligned with Germany's, the language is identical, and the cultural dynamics of selling to a DSO or Stadtwerk are similar enough that a German sales playbook transfers with minimal adaptation. NextKraftwerke followed this path explicitly, establishing Austrian operations before expanding further. From Austria, the logical next markets depend on product type: for software with minimal localization requirements, the Netherlands and the Nordics offer open, digitally mature grid markets with English as a working language. For hardware or deeply integrated software, France and Spain require more deliberate preparation — different procurement cultures, different regulatory bodies, and a strong local preference for domestic suppliers.

The Local Preference Bias Is Real. Critical infrastructure customers strongly prefer local providers — a German DSO will default to a German startup, a French DSO to a French one. The practical implication is that internationalization almost always requires some form of local presence: a local hire, a local partner, or

at minimum a local reference customer who can vouch for the product in the target market's language and context.

Regulatory Divergence Is the Real Barrier – Build for It Early. While the technical requirements of grid operation are largely harmonized across the EU, regulatory frameworks remain stubbornly national. Market design rules, grid fee structures, flexibility market access conditions, and DSO procurement regulations all differ by country and in some cases by region within a country. Germany's regulatory framework is among the strictest in Europe, which has a silver lining: a product that is fully compliant in Germany is typically compliant everywhere else, making Germany a credible proof point for European expansion. The markets that diverge most significantly from the German model, e.g. France with its single national DSO Enedis, the UK with its post-Brexit regulatory independence, and Switzerland with its distinct market structure, should be treated as separate GTM motions rather than extensions of a European playbook.

What we test in diligence

We look for a named economic buyer, a controlled success metric, a realistic procurement path, reusable integrations, evidence for switching costs, and a country-expansion plan grounded in local requirements. Claims based only on interview experience remain hypotheses until customer data confirms them.

Closing note

Grid markets can reward deep technical and regulatory knowledge, but the route to scale is uneven. The investable companies are those that convert a specific operational problem into measurable customer value and then show that the implementation can repeat.

Talk to us

If you are building in industrial or commercial demand response, thermal flexibility, fleet V2G, the aggregation layer, DSO-facing intelligence (transparency, forecasting, or execution), or mid-market OT security – we would like to meet you early. Vireo Ventures is a Berlin-based venture capital firm backing early-stage founders who build Europe’s future energy tech stack, investing at pre-seed and seed across Europe in electrification, AI for energy and physical infrastructure. HTGF is one of Europe’s most active VC investors, backing startups across key technology sectors, including Deep Tech, Industrial Tech and Climate Tech. As a multi-stage VC platform, HTGF supports founders from seed through growth, with follow-on and growth financing available through the DeepTech & Climate Fonds (DTCF) and the HTGF Opportunity Fund. Reach Anna Stetter (a.stetter@htgf.de) or Anja Senkmüller (a.senkmueller@htgf.de) at HTGF, or Felix Krause (felix@vireo.vc) and Matthias Engel (matthias@vireo.vc) at Vireo.

Glossary

TERM	MEANING
AgNes	“Allgemeine Netzentgeltsystematik Strom”: BNetzA's May 2026 framework concept that extends existing §19 StromNEV baseload network-fee relief for large industrial consumers through 2031 and defers the design of a future flexibility-oriented industrial tariff to a 2027 decision process.
BESS	Battery Energy Storage System.
BEV	Battery Electric Vehicle
BNetzA	“Bundesnetzagentur”: German Federal Network Agency, the regulator responsible for electricity, gas, telecommunications, postal and railway markets.
BMS	Battery Management System, the electronics and software that monitor and control a battery's state, safety, and performance.
CHP	Combined Heat and Power
Digital twin	A live virtual model of the physical network used for planning and operations.
DR	Demand Response, shifting electricity consumption in reaction to price or grid signals.
FCR / aFRR / mFRR	The TSO balancing-services stack: frequency containment reserve, automatic and manual frequency restoration reserves.
IPP	Independent Power Producer, a private company that generates and sells electricity without owning a distribution network. Common owners of utility-scale solar, wind, and storage assets.
LDES	Long-Duration Energy Storage, storage spanning many hours to weeks.
MiSpeL	“Marktintegration von Speichern und Ladepunkten” (market integration of storage and charging points). BNetzA determination of 1 October 2026 defining how EEG-eligible and nettable electricity volumes are determined for storage and bidirectional charging points that both draw from and feed into the grid. Transition period until 30 September 2027.
MsbG / GNDEW	Germany's metering legislation, defines the smart-meter rollout obligations and quotas (in force).
MCS	Megawatt Charging System
NIS2 / NCCS / CRA / KRITIS / IEC 62443	The European and German cybersecurity framework for critical infrastructure: operator obligations (NIS2, NCCS, KRITIS), product obligations under the EU Cyber Resilience Act (CRA) for connected products, and the technical OT-security standard (IEC 62443).
OCPP	Open Charging Point Protocol
O&M	Operations & Maintenance, the ongoing management, servicing, and repair of physical energy assets such as wind farms, solar parks, and substations. Often carried out by specialist O&M providers on behalf of asset owners.
OT / IT	Operational Technology (systems controlling physical processes) vs. Information Technology.
PLC	Programmable Logic Controller, an industrial computer that automates and controls physical processes.
Redispatch / curtailment	Operator interventions that adjust or switch off generation to protect the grid; curtailed renewable energy is paid for but not used.

TERM	MEANING
RTU	Remote Terminal Unit, a device that collects data from field equipment and sends commands to control systems.
SBOM	Software Bill of Materials, a complete inventory of the software components, libraries and dependencies contained in a product
SCADA	Supervisory Control and Data Acquisition, the control-room systems operating the grid.
SF6	SF6 stands for sulfur hexafluoride, a gas used as an insulating and switching medium in electrical equipment. It is being phased out because it is a highly potent greenhouse gas.
SOC	Security Operations Center
Stadtwerke	Municipal utilities, often combining local grid operation, energy supply, and other services.
STATCOMs	Static Synchronous Compensators, power-electronics devices installed in the grid to regulate voltage and provide reactive power support, increasingly used as grids carry more inverter-based generation.
TSO / DSO	Transmission / Distribution System Operator. TSOs run the high-voltage long-distance grid (four in Germany); DSOs run regional and local distribution networks (~870 in Germany).
V1G	One-directional smart charging: the charger varies *when* and *how fast* an EV charges in response to prices or grid signals, but power only ever flows from grid to car.
V2G	Vehicle-to-Grid, using EV batteries to feed power back and provide flexibility.
VPP	Virtual Power Plant, many small assets aggregated and operated as one tradable unit.
§14a EnWG	German rule enabling grid-serving control of consumer devices (heat pumps, wall-boxes) in exchange for reduced fees (in force since January 2024).
§19 StromNEV	German network-fee rule granting reductions of up to 90% for constant or atypical consumption. BNetzA's May 2026 AgNes concept generally extends existing baseload relief through 2031 and leaves future industrial arrangements for a 2027 decision; flexibility-friendly reform is not yet adopted.

Methodology, sources, and disclosures

Reference calls. More than 25 structured interviews conducted May–July 2026 with operators and investors including Amprion, Axpo, Encevo, THÜGA, Rhebo, Envelio, EcoPhi, Inframind, EDP Ventures, FEV Ventures, Move Energy, and further TSO, DSO, and BESS-market participants who prefer not to be named. Quoted statements are used with the speakers' permission. Statements attributed to reference calls reflect interview findings and the authors' synthesis, not independently published data.

Status of legal and regulatory claims. Time-sensitive statements in this paper are classified as enacted and in force; formally adopted but not yet applicable; proposed or under consultation; announced by a company or government; or forecast/authors' judgment. The classification is stated in the text and supporting footnotes. Data cutoff: 3 August 2026. Two exceptions apply: BNetzA's MiSpeL determination of 1 October 2026 and its smart-meter rollout survey of 21 September 2026 are included despite falling after the data cutoff, because they materially change the rules for storage and bidirectional charging (Part IV) and the metering baseline (Part II).

Public sources. Material factual, legal and transaction claims are supported by native Word footnotes. Interview evidence and authors' judgments are labelled as such. Primary sources are used where available; secondary sources are used where they add necessary market detail.

Related material. A companion market map of ~90 European grid startups across the categories of this paper is published separately.

Notes

1. SMARD / Bundesnetzagentur, “Maßnahmenvolumen im Gesamtjahr stabil” (congestion management 2025), 30 March 2026. https://www.smard.de/page/home/topic-article/444/219906/massnahmenvolumen-im-gesamtjahr-stabil
2. ZfK, “Smart-Meter-Schlusslichter: Bundesnetzagentur geht gegen 77 Messstellenbetreiber vor”, March 2026 (BNetzA rollout data: 5.5% of all metering points; 23.3% of mandatory cases, 31 December 2025). https://www.zfk.de/digitalisierung/smart-city-energy/smart-meter-schlusslichter-bundesnetzagentur-geht-gegen-77-messstellenbetreiber-vor; Bundesnetzagentur, press release on enforcement proceedings against 77 metering point operators, 27 March 2026 (data as of 31 December 2025). https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2026/20260327_Aufsichtsverfahren.html; BNetzA survey press release of 21 September 2026 (https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2026/20260921_Rollout.html).
3. Bundesnetzagentur, press release “Bundesnetzagentur publishes 2025 electricity market data”, 4 January 2026. https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2026/20260104_SMARD.html; pv magazine, “Europe’s negative electricity price hours double in Q1 amid renewables surpluses, market imbalances”, 8 May 2026 (ENTSO-E Transparency data). https://www.pv-magazine.com/2026/05/08/europes-negative-electricity-price-hours-double-in-q1-amid-renewables-surpluses-market-imbalances/
4. Bundesnetzagentur, “Bundesnetzagentur presents latest considerations on reform of electricity network tariff system”, 27 May 2026 (AgNes preliminary concept; existing baseload arrangements generally extended through 31 December 2031; future industrial arrangements to be decided in early 2027; not a final tariff design). https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2026/20260527_agnes.html
5. EPEX SPOT, Trading Brochure, December 2024 (spot-market orders can be submitted in 0.1 MW increments); German TSOs, Prequalification Conditions for Balancing Services, 5 July 2024 (1 MW minimum offer size for FCR, aFRR and mFRR, with aggregation permitted). https://www.epexspot.com/sites/default/files/2024-12/Trading%20brochure%202024%20December%20%281%29.pdf and https://www.regelleistung.net/cdn/files/edf2d526-3540-4272-d421-08de8a5687c8/pq-bedingungen-2024_07_05%28englisch%29.pdf
6. Bundesnetzagentur, Monitoring Report 2023: 866 electricity distribution system operators registered in Germany. https://data.bundesnetzagentur.de/Bundesnetzagentur/SharedDocs/Downloads/EN/Areas/ElectricityGas/CollectionCompanySpecificData/Monitoring/MonitoringReport2023.pdf
7. Leonhard Birnbaum, CEO of E.ON, OMR Podcast no. 886, ‘Netze für die Energiewende’, 2025. Used as a paraphrased source, not a direct quotation. https://omr.podigee.io/962-neue-episode
8. Christoph Kost et al., Fraunhofer ISE, ‘Levelized Cost of Electricity: Renewable Energy Technologies’, July 2024, pp. 4–5. https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/EN2024_ISE_Study_Levelized_Cost_of_Electricity_Renewable_Energy_Technologies.pdf
9. Bundesnetzagentur, Bundesnetzagentur publishes 2025 electricity market data, cited above.
10. pv magazine, Europe, cited above.
11. NESO (UK National Energy System Operator), “Clean Flexibility Roadmap”, 2025. https://www.neso.energy/publications/clean-flexibility-roadmap
12. 50Hertz, Amprion, TenneT Germany and TransnetBW, ‘Network Development Plan Electricity 2037/2045, Version 2025, second draft’, 13 March 2026, pp. 4–5. 2045 net consumption: 868.7–1,195.1 TWh; gross consumption: 989–1,294 TWh. https://www.netzentwicklungsplan.de/sites/default/files/2026-04/EN_NDP-compact_2037_2045_V2025_2nd_draft_3.pdf
13. Enerdata, 2026, current as at 3 August 2026. https://www.enerdata.net/publications/daily-energy-news/germany-opens-first-45-gw-long-term-capacity-auction-under-stromvkg.html
14. ZfK, Smart-Meter-Schlusslichter: Bundesnetzagentur geht gegen 77 Messstellenbetreiber vor, cited above.
15. Messstellenbetriebsgesetz (MsbG) as amended by the Gesetz zum Neustart der Digitalisierung der Energiewende (GNDEW), 2023 (enacted, in force): rollout quotas of 20% of mandatory cases by end-2025 and 90% by end-2032. https://www.gesetze-im-internet.de/messbg/
16. Bundesnetzagentur, cited above.
17. ACER, ‘How electricity contract choices can unlock consumer flexibility and lower bills’, 2025 Monitoring Report. ACER reports that 59% of EU consumers remain on flat-price or regulated contracts and identifies uneven smart-meter rollout and data access as barriers. https://acer.europa.eu/monitoring/energy-retail-consumer-protection-2025; European Commission, COM(2026) 600 proposal, 17 July 2026, not adopted as at 3 August 2026. https://energy.ec.europa.eu/publications/proposal-regulation-amending-regulation-eu2019943-fostering-electrification-and-digitalisation_en
18. Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.
19. One European caveat: this fragmentation is a German specialty. France's Enedis operates about 95% of the continental distribution network, Great Britain has fourteen licence areas under six DNO groups, and three large Dutch DSOs serve nearly all connections – so both the sales playbook and the market-size math change at every border (see the GTM guide in Part VI on internationalisation).
20. E.ON, “E.ON acquires majority stake in envelio GmbH”, 2021; envelio company communications, 2026. https://www.eon.com/en/about-us/media/press-release/2021/eon-acquires-majority-stake-in-envelio-gmbh.html ; EU DSO Entity, “Digital Solutions for Handling Connection Requests”, 22 October 2025 (digital tools improve processing and transparency, while permitting, cross-stakeholder coordination and supply-chain constraints remain). https://eudsoentity.eu/news/dso-entity-published-a-new-report-on-digital-solutions-for-handling-connection-requests/; Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.
21. Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.
22. Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.

23. ENTSO-E, cited above.
24. Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.
25. European Commission, “Flagship projects AI.grids and data centre sustainability”, 4 June 2026. https://energy.ec.europa.eu/news/flagship-projects-ai-grids-and-data-centre-sustainability-2026-06-04_en ; Regulation (EU) 2026/1744 (Digital Omnibus on AI), entered into force 27 July 2026; Annex III high-risk obligations apply from 2 December 2027. https://eur-lex.europa.eu/eli/reg/2026/1744/oj
26. SMARD / Bundesnetzagentur, Maßnahmenvolumen im Gesamtjahr stabil, cited above.
27. Bundesnetzagentur, Bundesnetzagentur publishes 2025 electricity market data, cited above.
28. pv magazine, Europe, cited above.
29. TenneT, “Annual Market Update 2025”, April 2026. https://tennet-drupal.s3.eu-central-1.amazonaws.com/default/2026-04/Annual%20Market%20Update%202025.pdf; RTE, “Bilan électrique 2025”, February 2026. https://assets.rte-france.com/prod/public/2026-02/Bilan-electrique-2025-principaux-resultats.pdf
30. Bundesnetzagentur, press release on dynamic electricity tariffs, 2 December 2025 (supplier offer obligation in force since 1 January 2025; household smart-meter coverage c. 2.8% as of late 2025). https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2025/20251202_Stromtarife.html
31. § 19(2) StromNEV (enacted, in force; framework expires end-2028): individual network fees for atypical and baseload consumption with reductions of up to 90%.
32. Bundesnetzagentur, Bundesnetzagentur presents latest considerations on reform of electricity network tariff system, cited above.
33. BDEW, “Strom: Verbrauch nach Verbrauchergruppen”. https://www.bdew.de/service/daten-und-grafiken/strom-verbrauch-nach-verbrauchergruppen/
34. BDEW, Strom: Verbrauch nach Verbrauchergruppen, cited above.
35. IWU / research project dataNWG, structural data on the German non-residential building stock. https://www.datanwg.de ; Directive (EU) 2024/1275, Article 13 (building automation and control for technically and economically feasible non-residential systems above 290 kW by end-2024 and above 70 kW by end-2029). https://eur-lex.europa.eu/eli/dir/2024/1275/oj
36. IWU / research project dataNWG, cited above.
37. European Commission Joint Research Centre, Smart Thermal Networks in the European Union—2025 Status Report, cited above.; pv magazine, “German utility deploying 30 MW heat pump for district heating” (Enercity, Hanover), 22 April 2026. https://www.pv-magazine.com/2026/04/22/german-utility-deploying-30-mw-heat-pump-for-district-heating/
38. BDEW, Strom: Verbrauch nach Verbrauchergruppen, cited above.
39. Authors’ estimate based on German battery-electric vehicle stock and assumed average usable battery capacity. This estimates installed fleet capacity, not the capacity that is connected, available or V2G-capable.
40. The Mobility House, "German parliament removes key barrier to bidirectional charging", November 2025 (source for the abolition of double grid fees on storage and EV feed-in, effective 1 January 2026). Bundesnetzagentur, press release "Bundesnetzagentur erlässt Festlegung zur Marktintegration von Stromspeichern und Ladepunkten (MiSpeL)", 1 October 2026, https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2026/20261001_Mispel.html. Bundesnetzagentur, "Hintergrundpapier MiSpeL", 1 October 2026 (Az. 618-25-02), https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/ErneuerbareEnergien/EEG_Aufsicht/MiSpeL/DL/Hintergrundpapier.html?nn=1067830
41. EPEX SPOT, cited above.
42. Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.
43. ACER, ‘Cybersecurity network code for electricity’, accessed 3 August 2026. The NCCS applies risk-management rules to entities carrying out processes with sufficiently high cross-border impact, described as high-impact and critical-impact entities; it does not place every participant in the wider energy value chain directly in scope. https://acer.europa.eu/electricity/cybersecurity
44. Dragos, OT/ICS Cybersecurity Year in Review 2025, February 2026. https://www.dragos.com/resources/press-release/dragos-2026-year-in-review-new-ot-threats-ransomware
45. European Union Agency for Cybersecurity, NIS2 incident reporting framework; German Federal Office for Information Security, NIS2 implementation law in force from 6 December 2025. https://www.enisa.europa.eu/topics/state-of-cybersecurity-in-the-eu/threats-and-incidents https://www.bsi.bund.de/DE/Service-Navi/Presse/Pressemitteilungen/Presse2025/251205_NIS-2-Umsetzungsgesetz_in_Kraft.html
46. German Federal Government, KRITIS umbrella law entered into force on 17 March 2026. https://www.bundesregierung.de/breg-de/aktuelles/kritis-dachgesetz-2383682
47. Structured reference calls conducted by Vireo and HTGF with grid operators, cited above.