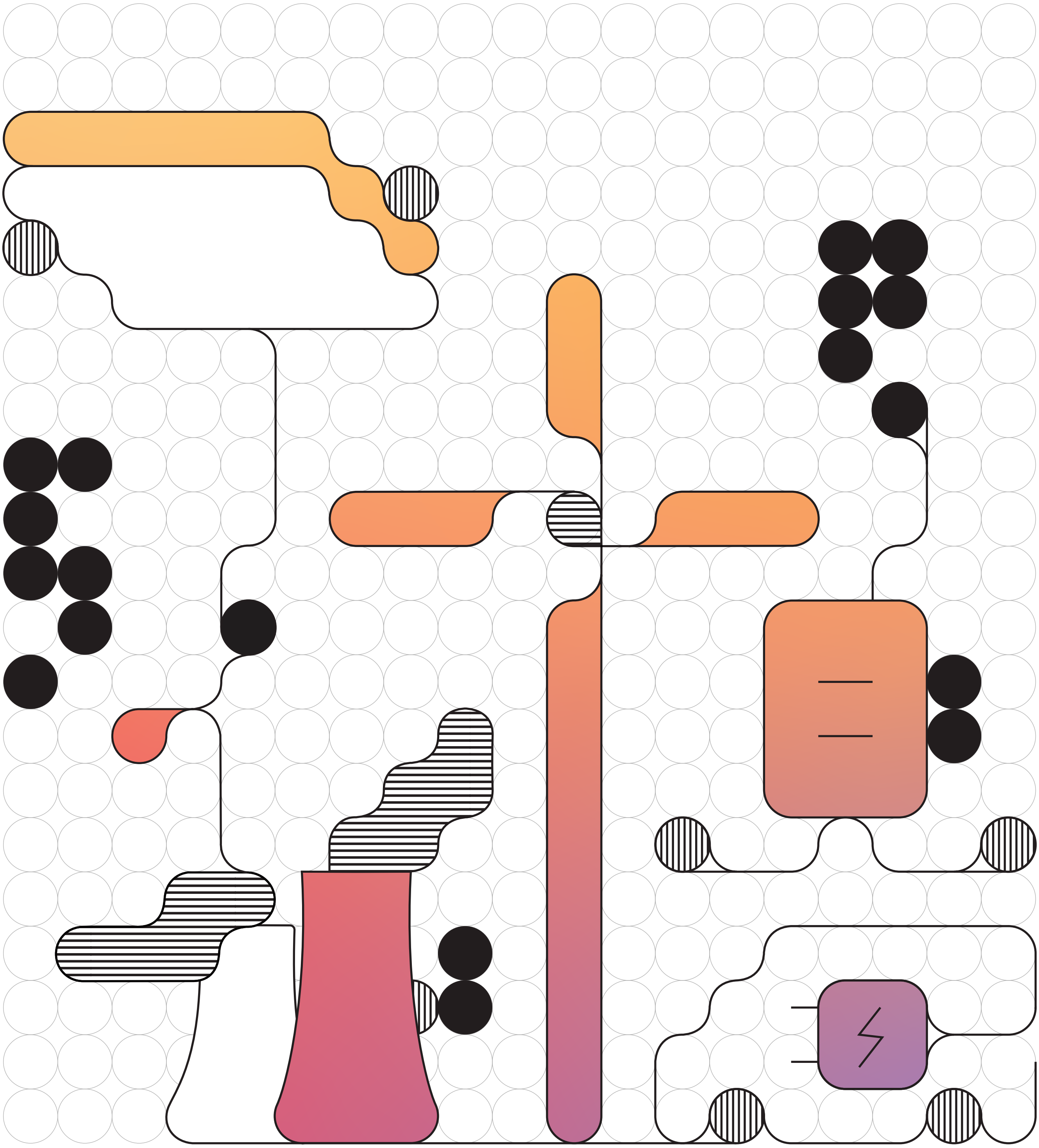
Digital Energy Grid

A vision for a unified energy infrastructure *(Abridged)*



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We are in the middle of one of the biggest energy transformations in history

The global energy landscape is undergoing a transformative shift, driven by decentralisation, digitalisation, and surging demand from electrification and economic growth. These shifts are reshaping how energy is produced, distributed, and consumed, presenting both unprecedented opportunities and complex challenges.

By 2035, nearly 3668 GW of rooftop solar PV is expected to be installed globally—a staggering 429% increase from today.[i] This expansion underscores the promise of decentralized renewables but also highlights the difficulty of managing distributed and variable resources. Global electricity demand is projected to nearly double by 2050[ii] under current policies and could rise even further under more ambitious scenarios. Key contributors include the electrification of heating, transport, industrial processes and increased energy demands from data centres. Emerging markets and developing economies are expected to drive nearly 80% of this growth by 2030.[iii]

This rapid demand growth and the proliferation of distributed energy resources (DERs) expose the urgent need for better coordination across the energy ecosystem. Technologies such as heat pumps and air conditioners are increasing demand sensitivity to temperature fluctuations, while extreme weather events like heatwaves place additional strain on power systems. Electrification is also altering hourly demand patterns, with peak demand rising faster than average demand in many locations —requiring significant investment in grid infrastructure.

Structural barriers and need for a new way of thinking

While policy-driven, market-based, and technological solutions exist to address these challenges, many are purpose-specific, targeting isolated issues rather than systemic needs. Current solutions, often fragmented and non-interoperable, impede the seamless integration of resources and stakeholders. For instance, limited grid visibility complicates the integration of variable renewables and DERs. Furthermore, the reliance on non-digital modes of operation exacerbates these challenges. Many processes lack portable, verifiable digital records, leading to information asymmetry and trust issues. Physical certifications for equipment that cannot be digitally verified and energy transactions without digital records hinder transparency, increase costs, and limit coordination. These fragmented and non-digital practices leave the ecosystem ill-equipped to adapt to the complexities of the energy transition.

To bridge these gaps, digital solutions offer a transformative opportunity; but only if designed for interoperability and systemic integration rather than in isolated silos. A truly decentralized energy ecosystem requires seamless coordination across three critical dimensions: information flows, energy flows, and transaction flows. Addressing these coordination challenges goes beyond deploying advanced physical infrastructure; it demands robust frameworks for sharing critical data such as demand, supply, and pricing signals. While advancements in smart devices, data analytics, and AI-based forecasting provide powerful tools, the underlying physical energy systems remain constrained by technical, financial, and infrastructural limitations.

The true challenge lies in synchronising the flow of information with the physical flow of energy across diverse stakeholders and distributed resources. A transformative solution lies in adopting an infrastructure-led approach: establishing a foundational digital infrastructure that moves beyond piecemeal solutions to embrace a shared, scalable framework. This concept can be envisioned as a data-grid to augment the physical energy grid, designed to handle the complexity and variability of modern energy markets.

A vision for a unified energy future

This paper introduces the Digital Energy Grid (DEG) as a conceptual blueprint for building a unified energy ecosystem. The guiding principle is to interlink the physical grid—comprising generation, distribution, loads and storage assets—with a digital "data grid" that encompasses everything from pricing signals to device identities and transaction histories. With that arrangement, we can shift from a traditional top-down network to a more adaptable, network-of-networks model, where each node (be it a microgrid, an aggregator's platform, or a prosumer's smart home) remains autonomous yet still interoperable with the rest.

By weaving together real-time data streams, operational signals, and secure exchange mechanisms, DEG sets the stage for a resilient, transparent, and innovation-friendly infrastructure. It raises the "playground" for diverse participants—utilities, regulators, communities, startups, large industries—fostering a more cohesive approach to shared goals like decarbonization, reliability, and affordability.

Key building blocks of the Digital Energy Grid

The Digital Energy Grid (DEG) centers on three interrelated elements that, when combined, enable seamless interoperability, scalability, and reliability.

Universal and interoperable identity for all energy assets and actors

The first cornerstone is establishing digital identities for each entity, actor and asset—ranging from power plants, transmission grids, and commercial battery farms to smaller devices like rooftop panels, electric vehicle (EV) batteries, or building automation systems. These identities act as globally unique references, akin to phone numbers or IP addresses in telecommunications. Just as standardized country codes for phone numbers and hierarchical zip code structures enable unique identification and interoperability across regions, universal energy identities can facilitate seamless integration and coordination across the energy ecosystem.

Machine- readable data formats

Beyond simple tagging, DEG insists that metadata—about devices, energy transactions, certifications, or consumption profiles—be expressed in a way that can be systematically processed by software. Instead of static documents or PDFs, the focus shifts toward open, machine-readable templates. Standardized, machine-readable energy data streams enable automation, intelligent decision-making, and efficient energy management, similar to how digital invoices enhance tax compliance.

Verifiability and portability of data

The final pillar is embedding robust verification procedures, which ensure that data—once registered or recorded—is cryptographically tamper-evident and remains portable across the ecosystem. This includes cryptographic signatures, proof-of-origin records, and permissioning models that uphold data sovereignty.

Together, these three building blocks—universal identity, machine-readable structures, and verifiability—represent the minimal infrastructure necessary to align physical energy flows with the information and transactional layers of a modern, distributed system.

From grids to networks: an interconnected energy world

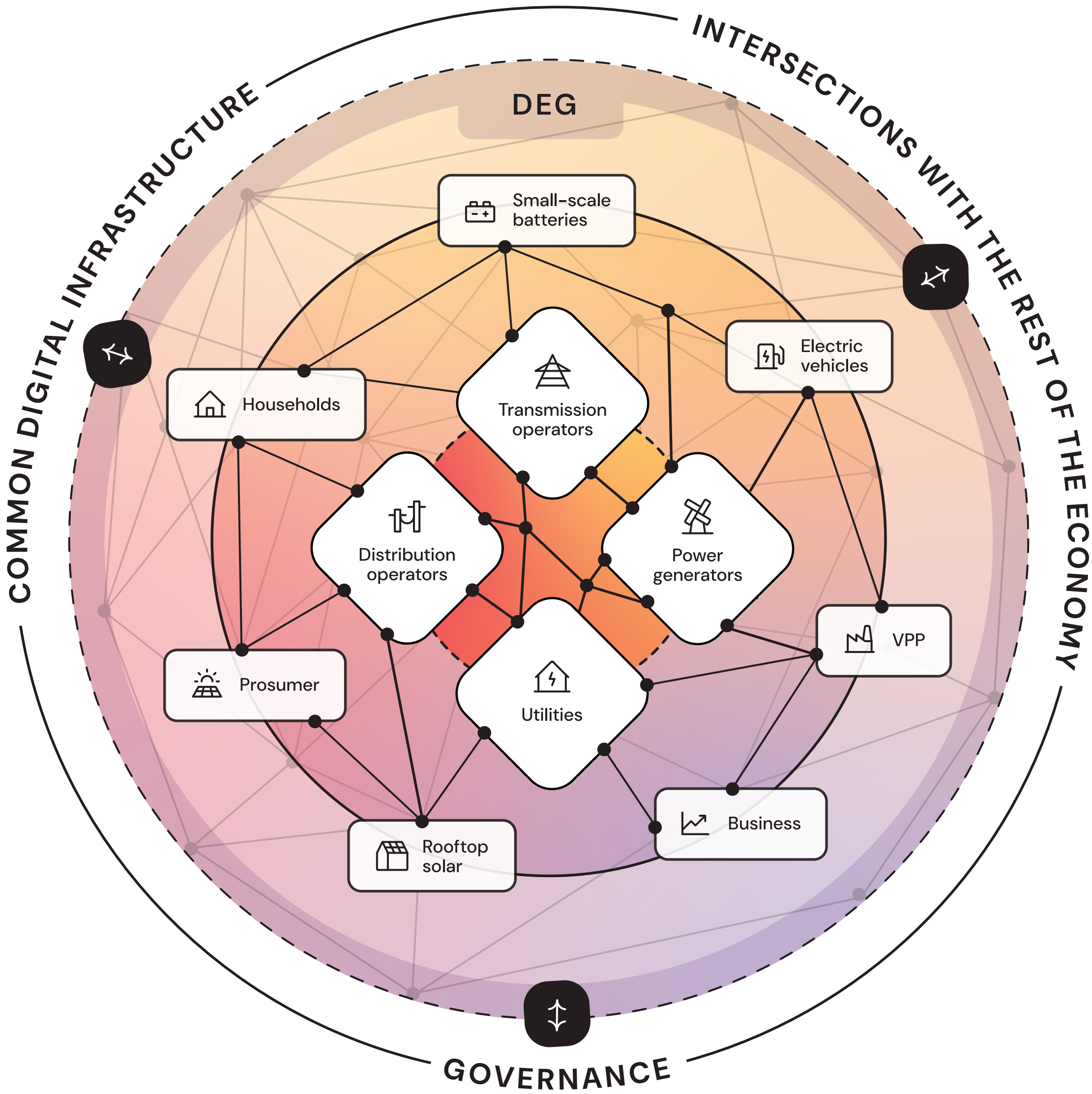

Figure 5: DEG vision encompasses all facets of the ecosystem

Bridging silos to capture combinatorial value

Historically, technological innovation has scaled through unification and infrastructure thinking, with purpose-specific advancements converging into broader, purpose-generic solutions. Minimal, standardized "packetization" of design and processes through open specifications has fueled rapid growth across industries—a pattern that could similarly drive efficiency, resilience, and sustainability in the energy sector.

Digital solutions, open standards, and advanced technologies like OCPP, OCPI, IEC 61850, and initiatives such as Project Mercury[iv] are already enabling targeted interoperability and communication for EV charging, DER management, and clean technology integration. Building on this progress, these efforts have successfully addressed specific needs, yet there remains an opportunity to unlock even greater potential through universal composability across the energy grid. A general-purpose foundation can amplify their impact significantly.

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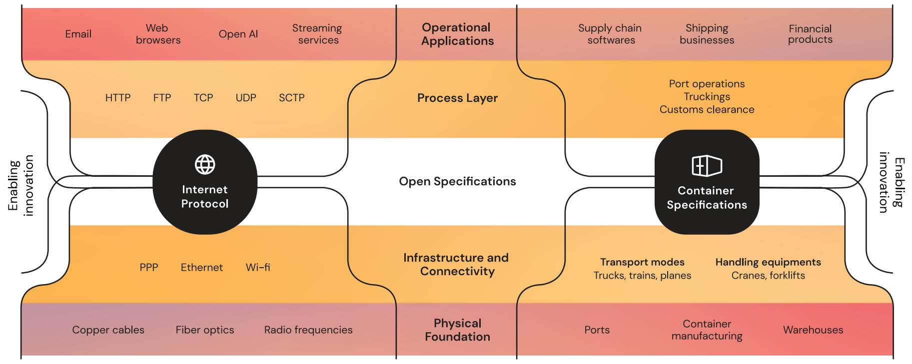

TCP/IP Protocol
Data packetization based on specifications allows diverse devices to exchange information seamlessly, commoditizing hardware and enabling applications like email, streaming & AI bots.

Logistics Standardization
Shipping containers revolutionized goods movement across transport modes, optimizing operations, enabling inventory management tools, and driving scalability.

Energy Sector Applications
Standardized delivery voltage, frequency, and lithium-ion battery cell formats foster interoperability, product innovation, and large-scale adoption across industries.

The Digital Energy Grid (DEG) can coordinate, complement, and unify existing solutions-without displacing them. By enabling true interoperability across systems, DEG provides the broader architecture on which these purpose-specific standards can be layered and expanded.

DEG as an evolutionary vision, not a single product

It's important to note that DEG is not a fixed piece of software or a proprietary technology stack. Instead, it is a vision for an evolving, interoperable, and modular set of digital rails spanning the entire energy sector. Over time, the ecosystem can accommodate new standards, tools, and security methods without fracturing. Legacy systems can gradually integrate, while advanced players adopt next-generation functionalities for even deeper automation or cross-sector linkages.

Here, we see infrastructure-thinking in action: the objective is not to enforce uniformity by discarding existing systems, but to extend an invitation for each actor to interconnect at the minimal required level. Just as the internet did not demand that all computers be made by the same manufacturer, DEG does not demand a universal software or hardware solution. Instead, it sets the stage so that all participants—from an off-grid micro-hydro unit to a cutting-edge AI-driven aggregator—can speak a shared digital language and produce verifiable records.

Illustrating the value: Different stakeholders, different needs

DEG offers wide-ranging gains for individuals, businesses, governments, and the energy sector at large. The section below highlights how various stakeholders in the energy ecosystem might experience the transformation once they integrate with a coherent digital network built on the principles of universal identity, machine-readable data, and verifiable records.

Consumers/Prosumers

Consumers and prosumers seek reliable and affordable energy with greater transparency and control. DEG can enable them to buy surplus energy or sell rooftop solar power in real time, benefiting from automated pricing and instant settlements. It can simplify subsidy and financing discovery, expediting approvals through digital verification. Secure, user-managed data sharing allows them to prove energy usage and capacity to banks or insurers, accelerating loan approvals and claims. DEG also enables fractional ownership in community renewable projects, ensuring transparent tracking of contributions and payouts.

Utility Companies/Grid Operators

Energy producers can maximize revenue and efficiency through DEG's streamlined regulatory processes, reducing approval times with machine-readable credentials. By dynamically matching supply with flexible loads in real time, producers may experience lower curtailment and improved return on investment. Transparent performance data can help ensure compliance with carbon markets, allowing participation in carbon credit trading with globally verifiable credentials. Additionally, DEG enables prompt settlement for energy delivered, leveraging verified production logs to enhance financial predictability.

Energy Market Operators

DEG can enhance market liquidity by enabling real-time bids from thousands of small producers and prosumers, creating highly competitive energy markets. Automated credential checks can ensure compliance while allowing rapid integration of new DER participants. Smart tools can reduce energy curtailment by efficiently pairing surplus power with flexible demand, while accurate pricing mechanisms capture the micro-level flexibility of consumer devices and distributed storage. DEG's automation may help lower transaction costs and accelerate settlement processes, ensuring efficient energy trading.

Regulators

Regulators can benefit from real-time, standardized energy data, supporting evidence-based policymaking and targeted subsidies. Automated compliance enforcement can reduce oversight costs while strengthening consumer protection and market transparency. DEG facilitates real-time tracking of emissions, renewable energy credits, and carbon offsets, streamlining climate reporting. Digitally encoded tariffs, safety standards, and incentives can ensure instant propagation across all energy participants, reducing regulatory bottlenecks and fostering innovation.

Financing Agencies

For financing agencies, DEG can provide tamper-proof asset performance logs, reducing risk and expediting due diligence. Transparent data can simplify the onboarding of micro-energy investments, such as community solar and aggregated storage projects. Real-time event triggers—such as battery downtime—can automatically release insurance payouts or loan disbursements based on verified conditions. Enhanced credit evaluations and ESG scoring allow lenders to assess project viability with confidence, ensuring alignment with global sustainability initiatives.

Market Players

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City Administrators

For city administrators, DEG can accelerate smart city initiatives by coordinating renewable energy projects, EV infrastructure, and public electrification under a unified digital system. Targeted incentives for local energy programs can create green jobs and promote shared energy ownership. Neighborhood-level energy data enables better urban planning, optimizing energy distribution and emergency response strategies. Automated policy enforcement and real-time sustainability dashboards help cities track progress toward climate and resilience goals efficiently.

Governments

Governments can leverage DEG to ensure stable and affordable energy supplies while advancing climate commitments. By integrating decentralized renewable energy sources, countries can reduce dependency on imported fuels and improve energy security. Real-time policy tracking enables agile adjustments to electrification and decarbonization efforts. DEG also enhances investment attractiveness by providing transparent, verifiable energy data, reducing risks for foreign and domestic investors. Scalable, modern grid policies can help ensure equitable access to clean energy, fostering economic growth and sustainability.

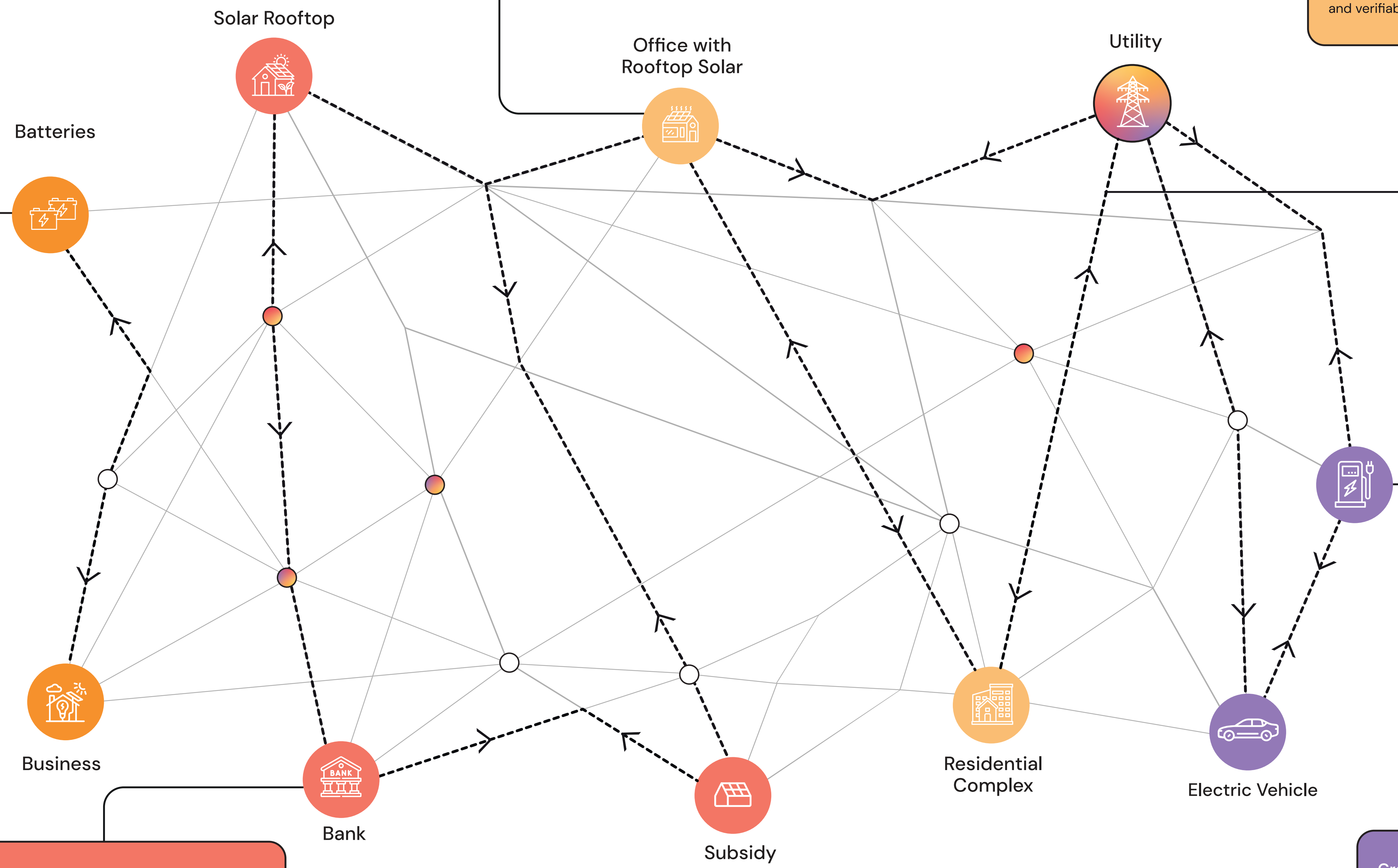
Imagining a world with DEG

Peer to peer trading

DEG enables seamless peer-to-peer (P2P) energy trading, letting producers sell surplus power directly to consumers. Households with rooftop solar or wind turbines can list surplus energy at dynamic prices, while EV owners, businesses, or homes can purchase it when needed. Secure, real-time data exchange ensures accurate metering, automated settlements, and trust in every transaction.

Smart Grid Resilience with Demand Response

DEG can enable seamless coordination across consumers with flexible electricity demand—such as commercial buildings, manufacturing plants, or electric vehicle charging networks. When grid operators signal the need to reduce load, DEG can allow stakeholders like factories, residential complexes and mobility hubs to adjust non-critical consumption in exchange for incentives. Real-time data ensures transparent tracking, automated settlements, and verifiable participation.



Cloud Energy Storage

DEG can transform energy storage into a dynamic, cloud-like resource, allowing businesses, industries, and homeowners to rent out their idle battery capacity to store excess energy and seamlessly share it with utilities, enterprises, or individual consumers when they need it. Utilities and users can access and aggregate these distributed assets in real time, optimizing energy use without costly new infrastructure.

Effective Solarisation

DEG unifies consumers, banks, installers, and agencies into a unified digital ecosystem for rooftop solar adoption. A single workflow replaces fragmented approvals, financing, and installation. Real-time data enables pre-approved financing, certified vendors, and transparent tracking, reducing a months-long process to

Green Charging & EV Charger Interoperability

DEG enables EV users to discover and access any nearby charger—of any make, model, company, or app—through a single interface. Users can also locate green charging slots powered by renewable energy. This seamless, interoperable experience reduces range anxiety, supports cleaner charging, and accelerates EV adoption at lower costs.

DEG and AI: A Symbiotic Relationship

AI and DEG are mutually reinforcing:

DEG Powers AI: DEG provides unified, high-quality datasets for AI models, enabling precise demand forecasting, grid optimization, and predictive maintenance.

AI Elevates DEG: AI enhances DEG's capabilities through real-time demand shifting, decarbonization opportunities, and seamless user interactions.

Together, DEG and AI can create a dynamic, adaptive energy ecosystem that optimizes supply-demand equilibria, integrates renewable energy, and drives decarbonization.

From Vision to Action

DEG is not a single product but a flexible framework designed for incremental adoption, adapting to local contexts and market readiness. Its implementation is guided by three key principles: context-aware adoption, enabling regions to integrate features like digital identities for rooftop solar or real-time data for demand response; future-ready growth, allowing modular expansion from basic functionalities to advanced services like peer-to-peer trading; and robust governance, ensuring inclusivity, fairness, and competition while preventing exclusion and promoting sustainable growth.

Call to Action

The **Digital Energy Grid (DEG)** offers a transformative vision for the energy sector, addressing the challenges of decentralization, digitalization, and rising demand. By unifying energy, information, and transaction flows, DEG enables a resilient, transparent, and inclusive energy ecosystem. Realizing this vision requires collective action from governments, industries, innovators, and communities. Together, we can build a sustainable, equitable energy future.

Bibliography

i - Iea. (n.d.-aa). World Energy Outlook 2024 – Analysis. Retrieved from https://www.iea.org/reports/world-energy-outlook-2024

ii - Iea. (n.d.-aa). World Energy Outlook 2024 – Analysis. Retrieved from https://www.iea.org/reports/world-energy-outlook-2024

iii - Iea. (n.d.-aa). World Energy Outlook 2024 – Analysis. Retrieved from https://www.iea.org/reports/world-energy-outlook-2024

iv - Octopus Energy unveils "Project Mercury" – a global vision for a smart energy tech ecosystem. (n.d.). Retrieved from https://octopus.energy/press/project-mercury/

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