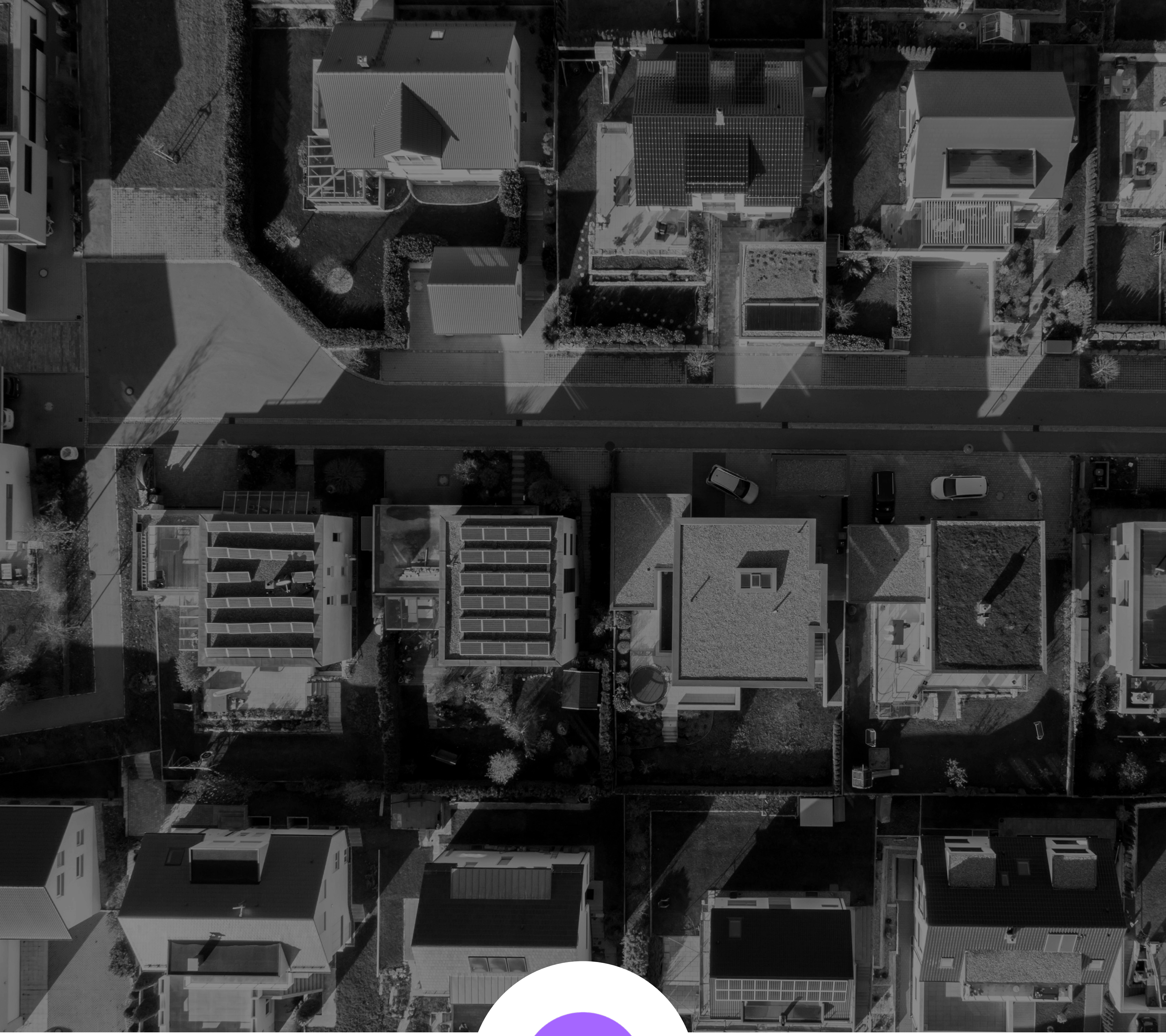

energy web

EW-DOS: The Energy Web Decentralized Operating System

An Open-Source Technology Stack to Accelerate the Energy Transition

December 2019

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Key Takeaways

- After three years of requirements gathering, experimentation, and prototyping solutions with the global energy blockchain community, Energy Web Foundation (EWF) is evolving its technology roadmap to focus on two primary use cases: enhancing energy sector traceability and unlocking grid flexibility from customer-owned resources.
- To support enterprise-grade solutions in these domains, **we are transitioning our technology approach from a blockchain-only architecture to the Energy Web Decentralized Operating System (EW-DOS), a stack of open-source software and standards that includes the Energy Web Chain.**
- EW-DOS leverages self-sovereign decentralized identifiers, a series of decentralized registries, messaging services, and integrations with legacy information technology (IT) systems to facilitate transactions between billions of assets, customers, grid operators, service providers, and retailers. This stack is a common digital infrastructure that's owned by none but managed and maintained by all.
- To achieve our mission, EWF is developing and deploying EW-DOS with market participants globally. Two initial deployments are already under way: integrating small-scale customers into the wholesale balancing market for a European transmission system operator and bringing to life a first-of-its-kind renewables marketplace in Southeast Asia with PTT.

This paper explains EWF's refined vision for leveraging blockchain technology to accelerate the energy transition, based on the past three years of research and collaboration with our network of more than 100 energy market participants. It is intended for general energy and technology audiences. For a more detailed technical description of EWF's current technology and roadmap, please see this paper's companion piece:

https://www.energyweb.org/reports/EWDOS-How-It-Works/

Preface

Energy Blockchain and EWF

Since our founding in early 2017, Energy Web Foundation (EWF) has delivered on its initial vision. The energy sector's first public blockchain—the Energy Web Chain (EW Chain)—is live. EWF has also released a series of open-source software development toolkits (SDKs) enabling market participants to more-easily launch new digital solutions that support the global transition toward low-carbon energy systems.

This was accomplished with EWF's 100+ member organizations, the world's largest energy blockchain ecosystem, representing 280 million customers.

The energy blockchain space is maturing quickly. From Thailand, to Austria, to California, to Latin America, major energy market participants have already launched or are in the process of launching first-of-their-kind, enterprise-grade energy blockchain products on the EW Chain.

Meanwhile, the EW Chain itself is one of the only public blockchains among any industry worldwide whose validator nodes are run by known corporations, many of them some of the largest and most-respected energy companies globally. To date, we count more than 25 established companies hosting validator nodes across 15 countries spanning 17 time zones.

We are proud of the technology groundwork we have laid, the ecosystem of market participants we have fostered, and the initial solutions being deployed that leverage the EW Chain and our SDKs. But our mission **to accelerate the global transition to a low-carbon future using decentralized and digital technologies** is far from complete.

Over the past three years we've worked with our member organizations to research and test more than 100 use cases for blockchain in the energy sector, developed dozens of proof-of-concepts, and supported the launch of commercial applications. Along the way, we have learned the following:

- Blockchain technology is uniquely capable for establishing multi-party consensus, anchoring trust, and providing proofs. **It should be used accordingly, and not primarily as a datastore or messaging platform.**

- **Open-source software and decentralized system architectures are critical to unlocking value in the energy sector with digital technology.** Open-source and open architectures minimize transaction costs, avoid vendor lock-in, and support standardization and interoperability.

- Simply "adding blockchain" when attempting to solve a problem does little. **Taking advantage of blockchain's full potential requires reimagining business and market processes—including the roles and responsibilities of different actors—while embracing new decentralized architectures.**

- Blockchain is not a replacement for legacy information technology (IT) systems in the energy sector. **Blockchain should integrate with and augment legacy IT.**

- **The Energy Web Chain is capable of supporting enterprise-grade applications** with respect to scale, cost, and data privacy—as long as solutions are designed with the right architecture, leveraging the blockchain for its strengths.

With these lessons in mind, we have narrowed our focus to support what we believe to be the two most-valuable use cases of blockchain technology in the energy sector: enhancing energy sector traceability and unlocking grid flexibility from customer-owned resources.

Our plan is to now work with some of the world's largest energy companies to develop and deploy a new technology stack focused explicitly on these use cases. We call this enhanced tech stack the **Energy Web Decentralized Operating System (EW-DOS)**.

Our vision is for EW-DOS to become a *de facto* industry standard: a secure, open-source, shared operating system for the 21st century grid. It is a stack of software and standards, including the Energy Web Chain, that will enable market participants to digitally orchestrate low-carbon electric systems.

The Challenge

Customers are on track to invest more in the grid than utilities by 2030. But today's power grids and electricity markets are not designed for a customer-centric future.

Utility-scale wind and solar are now the cheapest sources of electricity in most regions of the globe. Renewable generation will comprise an estimated 50–80% of overall capacity in the coming decades, largely replacing thermal generation assets. This alone represents the most dramatic shift in the electricity sector since the advent of alternating current.

But perhaps more significantly, for the first time in over a century individuals, companies, and communities can switch to local, independently-produced power at prices competitive with grid supply by investing in a mix of large-scale renewables and distributed energy resources (DERs, including distributed solar PV, energy storage, electric mobility, combined heat and power, energy management systems, and "smart" appliances such as thermostats).[1]

[1] Customer investment and DER deployment data based on EWF analysis of Bloomberg New Energy Finance's *New Energy Outlook*, S&P Global Intelligence, and Rocky Mountain Institute internal data.

Customers are making the switch quickly: in the next ten years, electricity end-users will spend a cumulative $830B on DERs and $7T on electric mobility. By 2030, roughly a third of global installed capacity will reside "behind the meter" (see Figure 1). Along with this massive investment shift is a coming tsunami of device interconnections: **an estimated 3.5 *billion* internet-connected DERs are expected to integrate with existing electric grids by 2030**.

Taken together, these assets have the potential to form the basis of decarbonized, flexible, resilient energy systems the world-over. But there's a fundamental problem: everything about today's electricity markets—from rules governing asset qualification, to the way prices are set, to the systems used to monitor and manage the grid—assumes that supply is controllable, demand is fixed, and grid investment is a centralized function driven by grid operators.

These assumptions are no longer valid. Supply from renewables is variable, demand is becoming flexible, and customer investment in energy is projected to eclipse grid operator investment over the next decade—investment taking place in a naturally decentralized way: some customers want backup power, others want to lower their energy bill or carbon footprint, and others simply want to control smart appliances remotely.

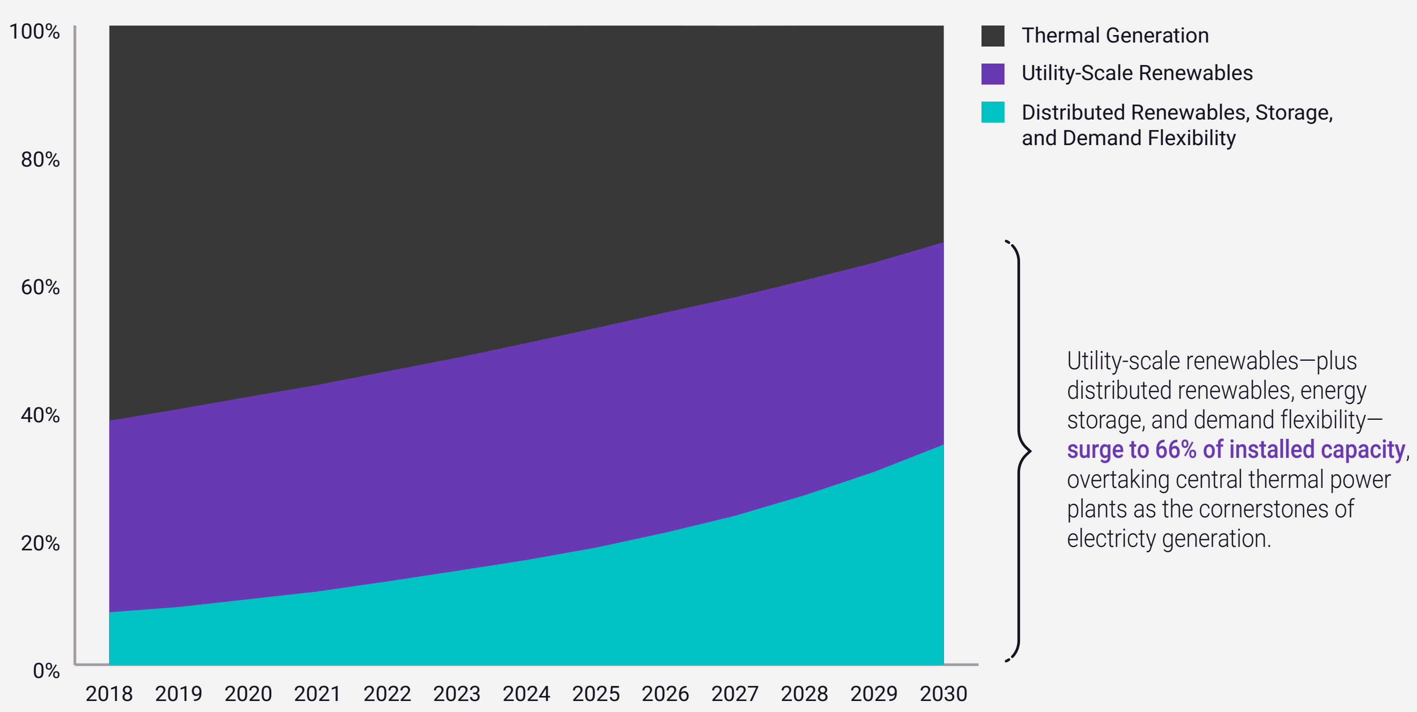
In this environment, **asset and customer information is fragmented across multiple siloed systems and is often invisible to grid operators.**[2] Consequently, many assets remain largely isolated from core system planning and operation functions, and DERs in particular are chronically underutilized and frequently fail to capture their full potential value.

We aim to overcome these issues with EW-DOS.

[2] We use the term "grid operators" as a catch-all for entities responsible for administering markets and/or processes that maintain overall supply-demand balance on the grid. Terminology varies by geography and regulatory regime, but includes vertically integrated utilities, transmission system operators, distribution system operators, market operators, independent system operators, and regional transmission operators.

Fig. 1

Global Installed Capacity by Resource Type



The Opportunity

Use decentralized technologies to enhance energy-sector traceability and unlock grid flexibility from customer-owned resources.

Bigger databases, more-efficient algorithms, or faster computers alone will not overcome the challenges facing grid operators. The problem is today's grid architecture.

Centralized architectures like the ones used to operate the grid today ultimately place the burden on a single party to maintain infrastructure, administer user roles and permissions, update data based on events over time, and establish a secure way of coordinating data across multiple discrete technical and organizational boundaries on a permissioned basis. In such architectures, data is duplicated across systems, which increases the risk of inconsistencies. This in turn leads to low trust and high cost.

Instead, we believe market participants ranging from regulators to grid operators to customers need to fundamentally re-evaluate their respective roles and responsibilities. We believe in democratizing the way renewables and DERs are integrated into grids, such that:

- Regulators set high-level rules of engagement;
- Grid operators provide platforms for transactions as well as visibility into outcomes;
- Individual customers, retailers, DER installers, and other actors perform many administrative functions that currently reside within grid operators.

Our vision is to develop and deploy EW-DOS, a stack of open-source decentralized technologies and standards to meet global requirements for establishing identity, enforcing rules, and facilitating transactions between billions of assets, customers, utilities, service providers, and grid operators.

With EW-DOS, we can support widespread value creation via the two most-promising use cases we have uncovered to date:

1. **Enhancing traceability in the energy sector,** giving market participants the ability purchase a variety of digitalized, attribute-based green commodities ranging from International Renewable Energy Certificates (I-RECs) to certified green electric vehicle charges or low-carbon fuels (e.g., biogas).
2. **Unlocking deep demand-side flexibility,** enabling grid operators to tap into the vast technical potential of customer-owned distributed energy resources in a trustworthy, low-cost, scalable way.

EW-DOS works by completely inverting today's system of top-down, unilateral management of energy-sector data acquisition and management.

Instead of any given person or device maintaining separate digital accounts for every product and service they use (i.e., duplicated identities among market participants) there's one universal and persistent identity controlled by the identity owner and accessible to all other market participants. When conditions change (e.g., a customer switching from one electricity retailer to another), there is no need to start the registration process from scratch. The identity owner simply updates its verifiable credentials, directs new relevant actors to its modified identity, and uses their identity to sign messages, perform transactions, and interact with market platforms.

Travel passports are the best analogy for describing how EW-DOS works. At a very high level, passports summarize who you are, where you've been, and where you're allowed to go or not go now and in the future based on a variety of factors. Passports are a global standard for verifying identity and credentials; individuals are granted specific permissions based on attributes like nationality and the rules of different jurisdictions; the passport itself contains both intrinsic data about you as well as dynamic data like visas and travel history, which evolve and update over time.

EW-DOS is a tool for similarly establishing digital "passports" for every customer, asset, service provider, and authority in a given electricity system. But instead of a central entity being in charge of verifying credentials and issuing the passport itself, any individual can create a passport and establish verified credentials over time through interactions with peers or various authorities.

Here's how digital identities fit into the EW-DOS architecture, step by step (see Figures 2 and 3):

- **Digitalize:** Any customer, market participant, or device that wants to participate in a given electricity market first establishes a self-sovereign digital identity to coordinate with other systems and participants. Every digital identity is anchored on the EW Chain and fully owned and controlled by its creator forever.
- **Authenticate:** Once identities are created, local grid operators and market participants need a system to authenticate them and know, for example, whether a given solar PV system in Asia or an electric vehicle in California is what it says it is and has the attributes it claims to have (e.g., power capacity, ownership). To do so, identity owners make claims to peers or relevant authorities such as grid operators and installers.

  Every claim is authenticated (or not) through bilateral transactions, in which the "claimer" (i.e., identity owner) provides a "verifier" (e.g., a DER installer) with agreed-upon documentation or data to prove a given credential. For a simple example, picture a DER owner claiming to a DER installer that they own a 5 kW capacity battery or solar PV system. As claims are verified, the underlying digital identity becomes richer and more trusted. Identity owners can also use claims to delegate other entities to perform transactions or claims on their behalf. Claim messaging and data storage can be done “off-chain” or “on-chain” depending on the application. The Energy Web Chain is primarily used for providing proofs about each identity, enabling market actors to achieve consensus about a given identity or claim without needing to share or expose underlying data.

- **Authorize:** Once authenticated, identities must then be authorized to participate in electricity markets or services for which they are qualified. To do so, grid operators, regulators, and/or retailers create registries that query the pool of on-chain digital identities and integrate all identities that meet defined eligibility criteria for any given market, product, or service. These registries enforce market rules or business logic based on the verified claims of digital identities, thus providing the foundational identity and relational data that other business processes and systems rely on—from market bidding, to dispatch, to settlement.
- **Operate:** With identities allowed into their respective registries, the corresponding customers and resources can participate in markets. For a traceability example, authorized wind plants may be added to an International Renewable Energy Certificate registry and begin producing digitally-unique I-RECs that authorized corporate buyers can purchase directly. For a flexibility example, authorized behind-the-meter batteries are added to a local transmission system operator registry and begin participating in the wholesale market for frequency regulation. Actual market operations are accomplished using a mix of decentralized architectures and existing information and operational technology systems, depending on the requirements of the specific application. Over time, operational and contractual data can be fed back to digital identities as verifiable claims to further augment the performance or “reputation” rating of each identity.

In this architecture, blockchain-based digital identities become the common reference point for all participants and systems within a given market. Just as real-world passports form the basis for establishing identity and permissions (e.g., the ability to travel or work) in any region, they are the basis for registering and monitoring the actions of assets and customers in electricity markets.

Fig. 2

Decentralized identifiers—enriched by multi-party attestation of verifiable claims—form the backbone of EW-DOS digital identities.

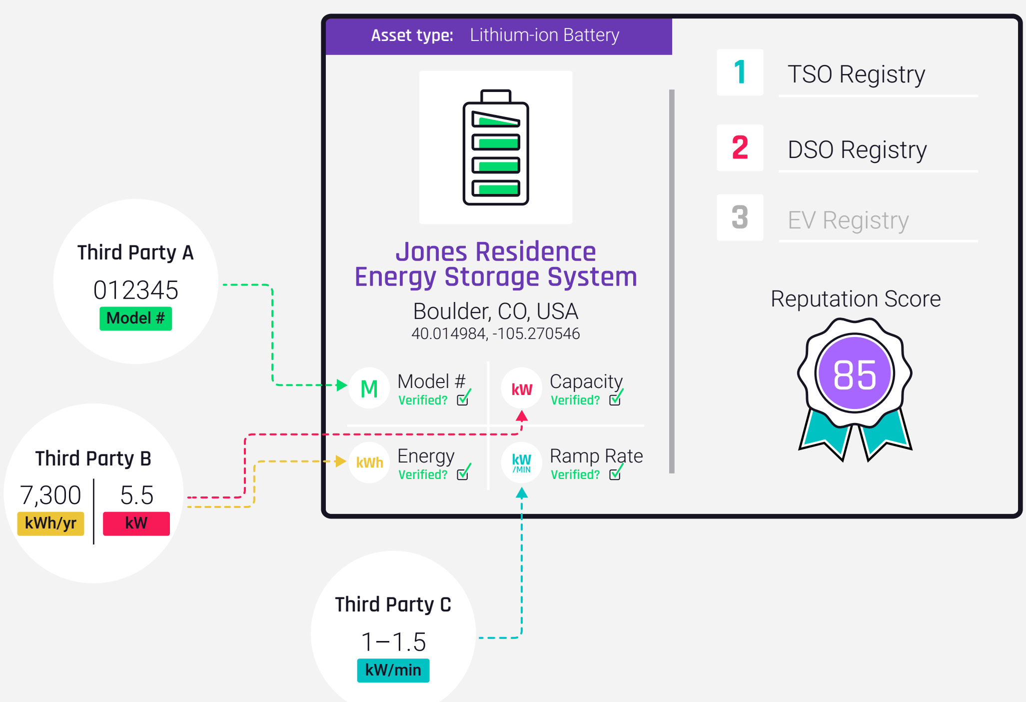
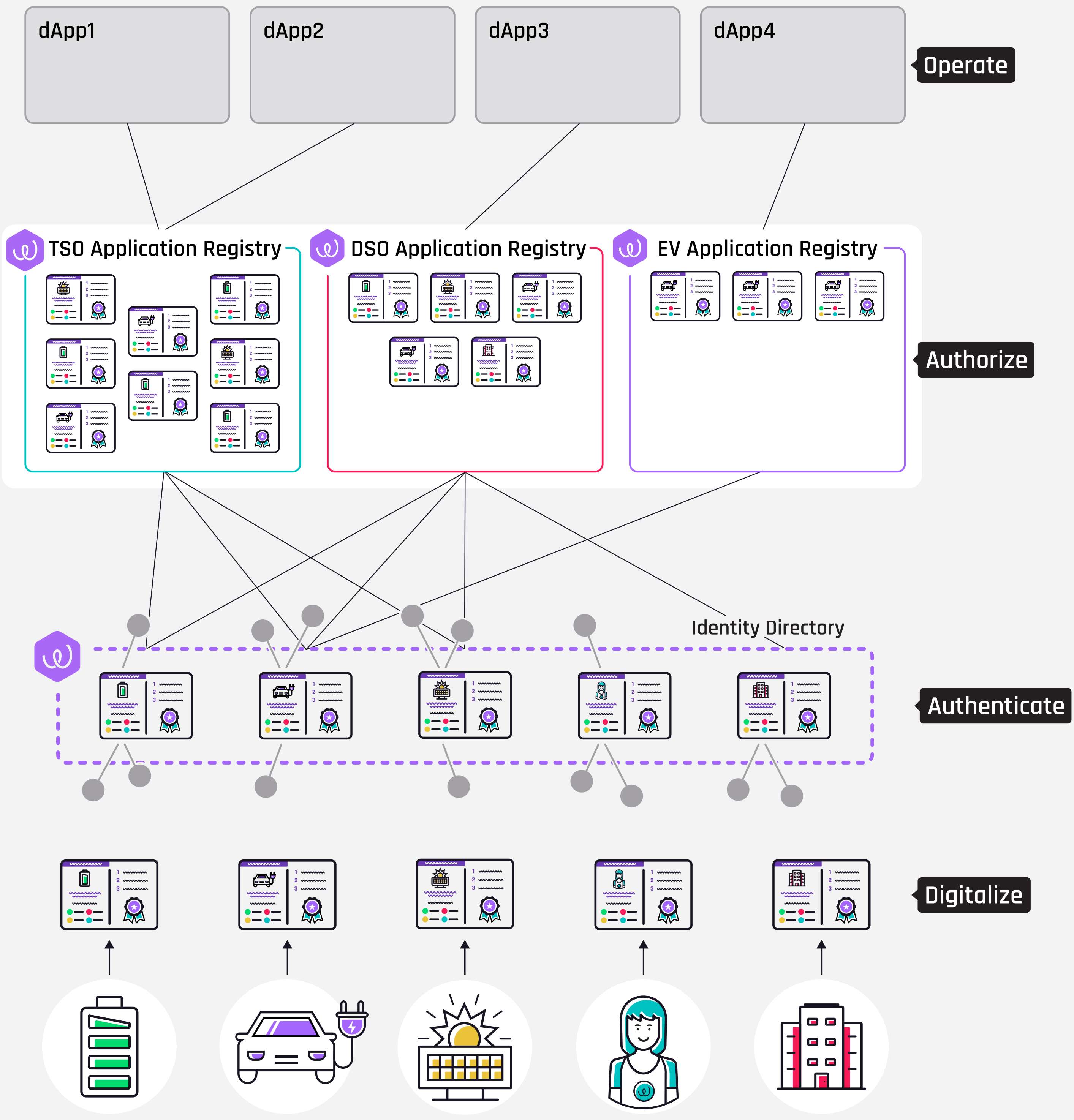


Fig. 3

'EW-DOS Passports' based on decentralized identitifiers (DIDs) reside in an Identity Directory that interfaces with various application registries.

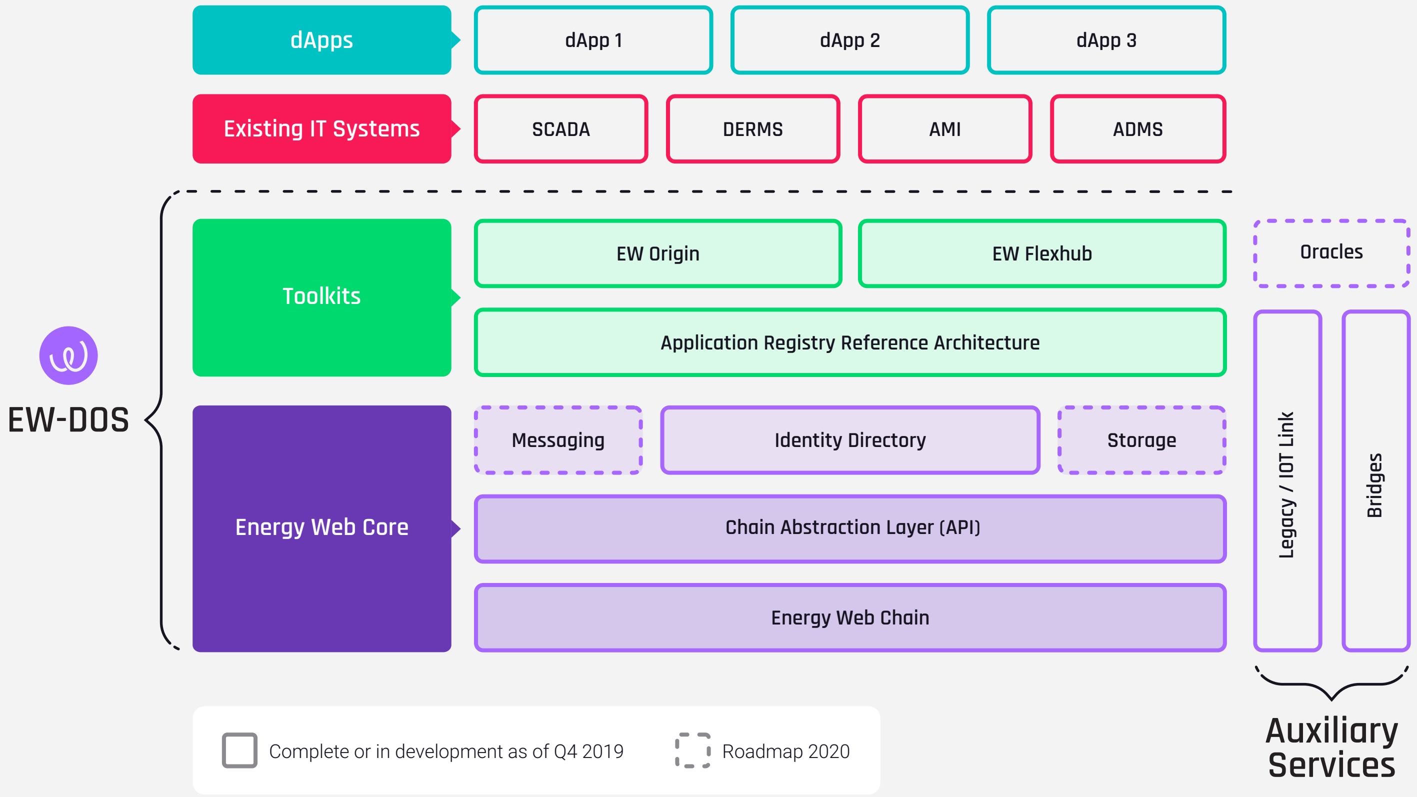


A Closer Look

The Energy Web Decentralized Operating System (EW-DOS)

Fig. 4

EW-DOS is our vision for a stack of open-source software and standards enabling market participants to digitally orchestrate low-carbon electricity systems.



In this section we describe at a high-level each component of EW-DOS.

EW Core

- **EW Chain:** A public, Proof-of-Authority blockchain operated by over 25 companies from 14 countries spanning 17 time zones. The EW Chain hosts decentralized identifiers, executes smart contracts, and provides proofs for verifying the state of data and events. It features a native token (EWT) and a suite of templates for creating all types of traceable digital assets.

- **Chain Abstraction:** Application programming interfaces (APIs) that provide a standard communication interface between on-chain components (e.g., decentralized identifiers and smart contracts) and off-chain systems and data. Analogous to middleware in a conventional operating system.

- **Messaging:** It's best practice to send messages (i.e. perform transactions) on blockchain only when the underlying data requires multi-party consensus. Most messaging between identities, contracts, and applications should be done off-chain using established standards (e.g., AMQP, MQTT, STOMP, COAP). EWF's messaging solution leverages these standards to establish a decentralized messaging option facilitating high-volume/low-latency messaging that can also be integrated with on-chain transactions and signatures.

- **Identity Directory:** The Identity Directory organizes decentralized identifiers (DIDs), which are self-sovereign digital identities that can be created and stored independently from a central authority. Think of a DID as a universal and interoperable online account that the user controls and can be used to log in to any platform or service. The identity holder (the "subject") can add as much information as they like to their identity (i.e., claims) and they can get this information verified by authorities (e.g., a government, energy company, bank). Collectively, this process authenticates an identity. These verified claims can then be used to selectively disclose information to third parties, akin to a person proving that they have a valid driver's license by showing the expiry date and the picture but without disclosing their home address, name, or age. The core Identity Directory is a smart contract that contains the universal list of DIDs and associated claims on the EW Chain. This architecture gives end users greater agency over how their digital identity (and associated data) is used and stored while also offering seamless interoperability with all decentralized applications running on the EW Chain.

- **Storage:** Given the volume of data in the energy sector, as well as the complicated regulations governing its use, it will be impractical to store data on blockchain at any reasonable scale. EWF is experimenting with various emerging decentralized storage solutions, but we expect that in most cases existing storage solutions (e.g., either private cloud or on-premise database) will be used for commercial applications and the chain abstraction layer will serve as a connective layer to on-chain components.

EW Auxiliary Services

- **Legacy and IoT Link:** EW-DOS does not replace existing IT systems but rather augments them by providing a mechanism for more-easily establishing identity and attributes for customers and energy-sector assets. EWF is developing multiple reference architectures for securely connecting legacy IT systems (e.g., CRM, ERP, billing engines) as well as IoT devices to on-chain components. Toolkits range from server-side integrations into big SCADA systems to small, lightweight implementations that can run on a small IoT device. Link toolkits make use of the messaging layer to communicate with other applications.

- **Oracles:** In many use cases, on-chain smart contracts and events require data inputs from off-chain events or systems. For use cases where it's beneficial to leverage multiple input sources (e.g., monitoring of local voltage for multi-party reconciliation, reporting of distributed solar for renewable portfolio standards accounting), EWF is building on top of emerging open-source protocols for establishing a network of independent nodes to provide event data to on-chain contracts.

- **Bridges:** As blockchain technology continues to mature, we expect multiple blockchain platforms and protocols to emerge for specific use cases and/or geographies. To enable identities and contracts running on the EW Chain to interact with peers on other blockchain networks, purpose-built smart contracts called bridges are used. Initial bridges are designed to transfer tokens between different blockchains, but over time functionality will expand to enable any arbitrary data or transaction to occur between networks.

EW Toolkits

- **Application Registry Reference Architecture:** EWF's application registry reference architecture provides market participants a standardized way to create bespoke registries with administrative features specific to a particular geography, market, or application. Application registries act as an "authorization" layer, setting the rules and roles for DIDs that wish to participate in the given market. For example, a national grid operator may create an application registry that dictates eligibility for participation in a wholesale market (e.g., DID must have verified claim as being a qualified DER and that claim must be signed by another DID that has a verified claim from the national regulator).

  Every decentralized application (dApp) running on the EW Chain will have at least one application registry, but a given application registry can be applied to multiple applications (in the example above, a distribution utility could coordinate with the national grid operator and use the same registry for a local congestion management program). EWF's reference architecture includes a series of open-source smart contracts and dApps for managing changes and updates to the registry and creating an audit trail of all interactions between DIDs within the registry.

- **EW Origin:** A series of customizable open-source software modules designed to support provenance and traceability use cases, including digital renewable energy marketplaces. Origin includes three core components: certificate issuance, tracking, and reporting systems, as well as extensions for electric mobility and battery storage tracking.

- **EW Flexhub:** A series of customizable open-source software modules designed to support grid balancing and demand flexibility use cases in a variety of regulatory environments. Examples include enabling vertically integrated utilities to launch device-agnostic "bring-your-own-device" demand response platforms to helping DERs participate in a variety of wholesale electricity markets. This toolkit was borne out of requirements to enable DER participation in a two-second balancing / frequency response market.

- **Other Toolkits:** We are continuing to develop additional toolkits for renewable energy, DERs, and electric vehicle market participation as we gather additional requirements from our global network of members. In-development toolkits include functionality that enable digital identities to settle payment; automatically conduct evaluation, measurement, and verification (EM&V); post value in escrow; and engage in complex transactions (e.g., financial contracts).

The Roadmap

EWF's Plan to Drive Impact at Scale

EWF's theory-of-change is simple. To achieve our mission we work directly with some of the world's largest energy companies—including utilities, grid operators, and others—to develop and deploy solutions based on EW-DOS.

We believe we can transform the energy sector, enabling new low-carbon market designs of all shapes and sizes (in both developed and emerging economies) by implementing EW-DOS in collaboration with major market participants. EWF has already begun to develop and deploy discrete pieces of EW-DOS with several market participants, including:

In Europe, EWF is helping a transmission system operator integrate grid-edge customers to participate in national balancing markets. A "prosumer" engagement platform enables the country's prosumers and hardware vendors to establish DIDs for themselves and DER devices. The DIDs then are used to establish claims about DER attributes, location, and capabilities to inform which market(s) the DER can participate in. For ongoing market participation, bids—whether submitted individually or as part of an aggregated pool—are linked to DIDs to prevent double counting in multiple markets or pools. Following activation events, DIDs serve as an anchor to reconcile operational and financial data, and ultimately execute financial settlement.

In Thailand, EWF is co-developing a renewables marketplace platform with PTT to simplify corporate renewable energy procurement across Southeast Asia. This digital marketplace platform uses DIDs and a shared registry to streamline the onboarding of existing and new renewable generation assets, helping buyers find options that meet their needs, indicate their demand for new renewable energy projects, improve transparency into energy use across their supply chain, and prove their purchases for reporting purposes. The marketplace also synchronizes with a solution developed for the issuing bodies of energy attribute certificates (EACs) to certify transactions using the DID standard and uses tokens to trace EACs through their entire lifecycle from generation to retirement. PTT's platform will also make it easier to link electric vehicle (EV) charging with I-REC purchases to position EVs as a new, large renewable energy buyer category.

These are only two examples, but they highlight three important points:

- **EW-DOS makes it possible to build private and/or proprietary solutions on top of open-source software and a public, decentralized network.** If a utility wants a completely walled-off network where they are the only party capable of confirming and rejecting DID claims (meaning they can restrict who does / does not participate in the local market), EW-DOS supports that. If that same utility wants all operational matters to be conducted in-house using legacy IT systems, no problem. EW-DOS does not prescribe a particular approach to privacy and is flexible enough to work in any context.
- **EW-DOS is market and regulation agnostic.** It creates value in vertically-integrated utility territories as much as fully deregulated competitive markets. It works just as well in established markets in Western Europe as it does in emerging economies.
- **EW-DOS is not a "use case" or an "application"; it is public infrastructure that supports companies that want to build solutions.** Like other infrastructure platforms such as telecommunications, the Internet, and blockchains like the EW Chain, the applicability of EW-DOS is limited only by the imagination. It enables myriad use cases and applications, especially those that leverage the swell of customer DER investment to envision a low-carbon, decentralized electricity grid.

Contributors

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About Energy Web Foundation

Energy Web Foundation (EWF) is a global, member-driven nonprofit accelerating a low-carbon, customer-centric electricity system by unleashing the potential of blockchain and decentralized technologies. EWF focuses on technology integration and development, co-creating standards and architectures, speeding adoption, and building community.

In mid-2019, EWF and its member organizations launched the Energy Web Chain, the world's first enterprise-grade, open-source blockchain platform tailored to the sector's regulatory, operational, and market needs. EWF also fostered the world's largest energy blockchain ecosystem, comprising utilities, grid operators, renewable energy developers, corporate energy buyers, and others.

The Energy Web has become the industry's leading energy blockchain partner and most-respected voice of authority on energy blockchain.

For more, visit https://energyweb.org.

Learn More

For a more-detailed technical description of EWF's current technology and roadmap, see this paper's companion piece, ***EW-DOS: How It Works***.

To explore EWF's existing technology stack, visit our Github and Wiki.

To learn how to work with EWF, contact us at info@energyweb.org.

To learn more about EWF's mission, visit energyweb.org.

Appendix

EW-DOS in Context

New energy market designs are coming fast. Along with them, so are shifts in roles and responsibilities across grid operators,[3] retailers, and customers.

There are growing trends toward dynamic retail tariffs, local electricity markets, exposing retail customers to wholesale markets, and even "peer-to-peer" or other types of transactive energy markets that clear from the bottom up. With this context, there is a clear and urgent need to transition customers—and their assets—from being a passive "end point" in a complex supply chain to becoming active participants in a dynamic energy system.

Novel market designs and regulations are a necessary step towards achieving the energy transition. For example, in some jurisdictions, retail customers are prohibited from providing services to wholesale markets. But passing policy is only the first step, and implementation is much more easily said than done.

Even in instances where DER market participation is allowed (e.g., aggregation in competitive western Europe, California's DRAM program), established processes that grid operators use to integrate large-scale resources simply don't scale to customer-owned DERs. Other factors add further complexity, such as the arcane rules and systems that govern customer, DER, and grid data. Maintaining an accurate state of both the physical and financial relationships between customers, DERs, and other market participants (e.g., aggregators, service providers, and installers) is costly.

As a result, there is a high barrier to entry for integrating DERs to the grid and operating them to achieve a net benefit for all system participants.

[3] We use the term "grid operators" as a catch-all for entities responsible for administering markets and/or processes that maintain overall balance between supply and demand on the grid. Terminology varies depending on geography and regulatory regime, but this list includes transmission system operators, distribution system operators, market operators, independent system operators, and regional transmission operators.

New market designs are providing pathways for expanded renewable and DER participation, but leave unanswered important logistical questions about how to efficiently do it.

From Community Choice Aggregation in the United States, to DER participation in wholesale markets in Australia, to TSO-DSO Coordination in Europe, policymakers in developed electricity systems are experimenting with new designs to better accommodate new types of resources and achieve societal goals related to decarbonization, customer choice, and equity. In Africa, governments and businesses are looking to new policies and technologies to simultaneously decarbonize and expand access to energy in the face of changing climate and demographics. Despite differences in local conditions, there is nearly universal alignment on the need for a more distributed, renewable, resilient energy system. The question facing local leaders is no longer what to do, but how exactly to do it.

In terms of scale, impact, and intricacy, this challenge of integrating DERs into electricity markets is analogous to another industry currently undergoing widespread transformation: financial services. Globally, an estimated 1.5 billion adults are currently "unbanked" and lack access to traditional financial products ranging from checking accounts to lines of credit. Myriad reasons account for why so many people remain unbanked, yet three prominent barriers come to the forefront: 1) cost of those services, 2) lack of access to financial institutions, and 3) lack of proper documentation and identity verification. In short, existing systems for performing "know-your-customer" (KYC) checks and basic account management are either too complex or costly for billions of people living in rural and/or developing economies.

Similarly, in both developed and emerging electricity markets, most DERs are a) too small individually for large grid operators to care about, b) not worth the expense to justify traditional processes for enrolling, and/or c) simply invisible to local grid operators. Yet there will soon be far too many of them (DERs) to ignore or exclude—in both number and capacity.

It's wildly impractical for a grid operator to physically commission every single smart thermostat in their territory, or to run dedicated fiber optic lines to every distributed solar PV or energy storage system. The administrative burden of managing financial assurances for kilowatt-scale assets vastly outweighs the value of each asset's transactions.

For these reasons, to date the primary way—often the only way—for DERs to participate in markets is via aggregators who pool DERs into groups big enough to matter for traditional electricity markets. Aggregation is an undeniably useful tool, providing benefits both to end customers as well as grid operators. But it does not solve the fundamental problems of onboarding and integrating DERs at scale and at low cost. Aggregation only outsources costly administrative duties to aggregators themselves. These operating expenses are why even aggregators typically exclude certain types or sizes of DERs due to the impact on company profit margins.

Thus, the global energy industry faces two fundamental barriers to widespread DER integration. First, there's the issue of system-wide resource optimization for tomorrow's electricity grids in a renewables- and DER-rich energy future. Second, there's the fundamental issue of onboarding, vetting, and sharing key information about DER attributes, capabilities, relationships, and behaviors that allows system-wide optimization in the first place.

With respect to system-wide resource optimization, tools like Advanced Distribution Management Systems (ADMs), Distributed Energy Resource Management Systems (DERMS), and microgrid controllers are already proven and continue to make progress.

[3] DERs such as solar PV with smart inverters, battery storage systems, and flexible loads are technically capable of providing multiple grid services to multiple stakeholders, including the customer, local distribution utility, and wholesale/transmission system operator. DER maximize economic value to all stakeholders when they are utilized for multiple services. See RMI Economics of Series or WattClarity.

Onboarding and integration remains the thornier problem:

- **Verifying Identity and Credentials:** Just as banks need to perform “know-your-customer” checks to verify the identity of potential customers, assess their suitability for various products, and manage risk, grid operators need to qualify and register every asset that provides services to the electricity grid. They in essence need to “know-your-device” (KYD).

- **Enforcing Market Rules / Allowing Market Access:** DERs, like any asset, must only be allowed to participate in markets or provide services for which they are legally, technically, and financially capable. Such qualifications may change over time due to varying physical performance and/or evolving contractual relationships. In the banking world there’s an established (albeit imperfect) way of tracking “reputation” and enabling any relevant provider to allow or reject participation in a particular financial service: the credit score. In the electricity world, there’s no analogous reputation rating for small assets.

- **Exchanging Information (and Value):** At any given time a grid operator and/or other parties (e.g., aggregators, retailers, customers themselves) may rely on a single DER to provide a variety of services. To make optimal operational (i.e., real-time) and investment (i.e., planning) decisions, those entities need to have a common and accurate view of the attributes, capabilities, and state of each DER, its physical surroundings, and its contractual relationships. Therefore the identity, relational, and operational data associated with each DER needs to be authenticated and shared efficiently with all market participants that need access (e.g., regulators, TSOs, DSOs, aggregators, OEMs, customers).

These are the challenges EW-DOS is purpose-built to solve.