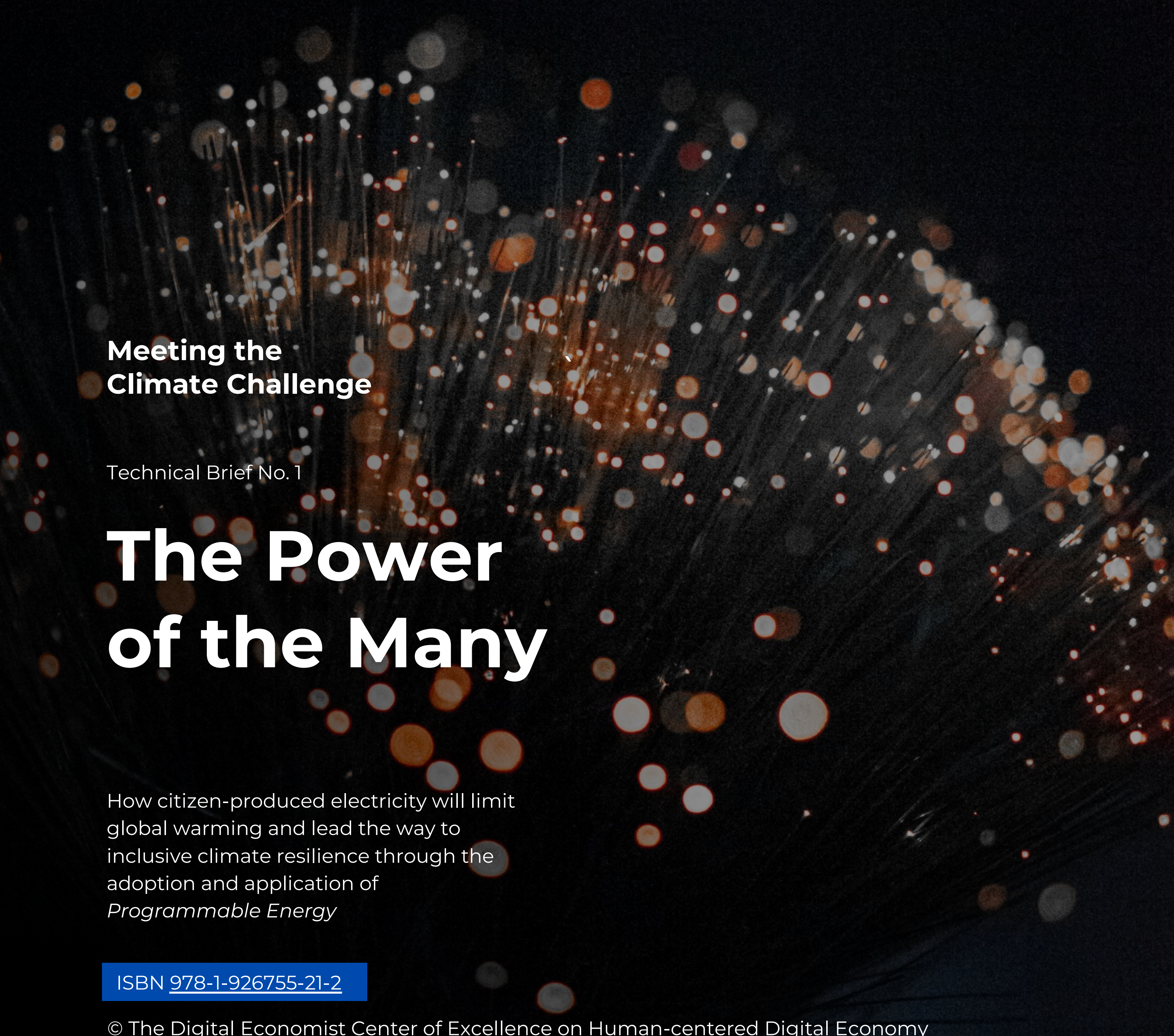

Meeting the
Climate Challenge

Technical Brief No. 1

The Power of the Many

How citizen-produced electricity will limit global warming and lead the way to inclusive climate resilience through the adoption and application of *Programmable Energy*

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Contents

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A note from The Digital Economist and the IBM Global Center of Excellence for Environment, Energy & Utilities

We have convened and converged our efforts in addressing the climate emergency.

This fourth paper in The Digital Economist's series under the heading Meeting the Climate Challenge is our first technical brief, joining the three policy briefs already published.

We present our joint thought leadership as both a provocation and an actionable roadmap, and look forward to opportunities to discuss our work and recommendations, particularly in relation to introducing and deploying the concept of Programmable Energy.

The Digital Economist (TDE) is a think tank and advisory: a global impact ecosystem focused on building insights, products, services and programs toward better human and planetary outcomes.

TDE Center of Excellence on Human-Centered Global Economy works with the priorities for climate adaptation and mitigation set by the Conference of Parties serving as the Parties to the United Nations Framework Convention on Climate Change (UNFCCC).

This technical briefing looks closely at the viability of tokenization as a tool to build the economics of Programmable Energy – a term coined by author Jos Röling – to bolster climate resiliency and sustainability.

IBM believes that through the application of intelligence, reason and science, we can improve business, society and the human condition, bringing the power of an open hybrid cloud and AI strategy to life for our clients and partners around the world.

Together, our objective is to inspire thinking that will fuel further discussion, collaboration and progress in this space.

To pursue discussion and dialog, please contact Jos Röling, CTO of EE&U and Blockchain at the IBM Consulting Global Center of Excellence, and Satya Brata Das, Senior Fellow, The Digital Economist Center of Excellence on Human-Centered Global Economy.

Executive Summary

As the climate emergency intensifies, people the world over rightly wonder how they can contribute to adaptation and mitigation, and specifically how tech can be harnessed to achieve inclusive climate resilience that will limit annual planetary warming to 1.5 degrees over pre-industrial norms. In this technical brief, we explore how ***Programmable Energy***, a concept developed by one of this paper's authors, Jos Röling, will play a significant role in the energy transition and inclusive climate resilience. Programmable Energy, consisting of electricity generated by individual citizens, with its value assured by tokenization and recorded on a blockchain, can be convened and converged to advance the sustainable generation of renewable electricity and to assign broad value to sustainable behaviors.

Recent military action has provoked a significant price surge in fossil fuels even while disrupting global supply chains and the whole industrial complex that depends on fossil fuels. This is compounding challenges already present as a consequence of the pandemic. The global economy is in flux, as the transition to more sustainable energy production gathers momentum at a pace unforeseen even just five years ago.

A key part of the accelerated transition is the rapid growth in distributed generation of electricity, principally through photovoltaic, wind and other renewable installations. The widespread adoption of autonomous power generation by citizens who both produce and consume electricity (prosumers) can be a significant asset in building climate resilience. Power grids were built and designed to link and serve large generators of electricity, leaving inherent systemic risk due to dependencies on sources that are few and far between. This risk has intensified with mounting climate disruptions which can leave a large power plant offline for days.

IBM and its partners have already begun to posit blockchain as a means of enabling prosumers to actively participate in generating and trading electricity and playing a role in improving the capacity and resilience of electricity supply and demand. In this paper, The Digital Economist's Center of Excellence on Human-Centered Digital Economy and IBM Consulting's Global Center of Excellence for Environment, Energy & Utilities seek to offer an actionable overview of use cases and technologies to incorporate the prosumer as a fully empowered participant in climate-resilient power generation and distribution.

Tokenization, along with other smart technologies (IoT, AI and analytics), allows us for the first time to create digital assets that can be exchanged between market participants in a manner similar to how physical goods are exchanged. Concurrently, the advancement of renewable energy generation and storage technologies enables us to complement the traditional capacities of the grid, including developing independent microgrid systems and a variety of energy aggregator business models. These new business models establish the market for renewable energy developers, increase climate resilience of aging grids and reduce our collective carbon footprint.

Fundamental to leveraging tokens for the energy market is what L. Lolkema from Afdeling Marktfacilitering, describes tokens as a new way to package energy. Different from the grid's physical continuous flow of energy, thinking of energy as a package creates the potential for market participants to transfer and trade kWh in the market. Jos Röling further defines this as **Programmable Energy**, which uses blockchain to enable us to slate its use for new market models.

The energy token allows energy trading either ex ante – for trading in the spot, futures or balancing markets – or post ante between counterparties trading excess generation with demand. This means the current way of selling energy can shift from the traditional model of power purchase agreements by bundling energy, either by consumption (e.g. community renewable energy assets), flexibility (e.g. EV charging) or appliances (e.g. buy hot water as a service). Energy tokens enable business models and use cases to track sustainability and offer green signals, achieve net-zero targets through the issue of carbon certificates and facilitate efficient allocation, clearing and settlement of energy units. It is this transition that allows customers (consumers) to become energy-responsible parties (prosumers). In order to stimulate this transition, leaders and innovators in the energy marketplace should use token taxonomies that are non-platform-specific, which will allow for an outcome- and impact-based digital framework. Gradual introduction of these tokenization models should accelerate the energy transition, ensure affordability and stabilize energy supply.

Over the last few years, we have seen a proliferation of innovative use cases leveraging different blockchain technologies to demonstrate the economics of energy token models. The blockchain-based, energy-focused use cases discussed below are well past proof of concept, beginning to demonstrate potential scalability across managing asset lifecycles, leveraging energy storage and grid balancing, trading in spot and futures markets, accelerating retail investment including digital green bonds, issuance of new assets (including community and alternative ownership) and managing energy access and usage mandates. For example, Equigy's crowd balancing platform aims to leverage consumer-invested batteries as a resource for grid balancing and strives to become a marketplace for TSOs and DSOs in Europe. Solstroem enables off-grid solar projects to access the carbon market, supporting the rollout of solar energy to the less privileged in off-grid rural environments with additional benefits of reducing deforestation activities, while also allowing access to mobile and banking services. In Africa, Irene Energy has successfully applied a multicloud deployment strategy to accelerate access to electricity and establish the back-office infrastructure for electricity roaming services. Power Transition in the UK is an innovative microgrid management platform that enables peer-to-peer energy trading that will begin granting consumer homes the ability to establish a local grid that can operate independently, creating a marketplace between residences during times of excess or power outage. Restart Energy Democracy (RED), an independent EU electricity and gas supply company, operates a decentralized energy supply platform to award green energy certificates to consumers of renewable energy.

Blockchain is also enabling new financial models for local renewable energy, from carbon credits and peer-to-peer to potential aggregation into investing mechanisms and green bonds. For example, The Green Digital Finance Alliance's report on Green Bonds and debt products observes that blockchain technologies can enable the aggregation of smaller-scale renewable energy projects into investable and traceable financial instruments whose efficiencies are tenfold those of traditional mechanisms. These findings were expanded in the Bank of International Settlement's Project Genesis report and pilots. In addition, organizations such as Evercity.io and Blockchain Triangle are actively building platforms automating issuance, management and impact monitoring including aggregated small-scale renewable energy projects.

Examples of successful supporting initiatives abound, but enabling the token economy in the power market will not happen overnight. Recently, IBM participated in a roundtable with 2Tokens to address the current challenges related to tokenizing energy. Participants arrived at preliminary recommendations around the following points:

1. Standardization of the token taxonomy and investment frameworks around smart grids, packaged energy, carbon markets and financing models with 2Tokens to follow up and deliver demonstration projects

2. Coordination across regulators overseeing investment, utilities, energy and tax policies to effectively remove barriers to adoption

3. Construction of decentralized marketplaces for energy

While the use cases elaborated on in this technical briefing reflect the successful tokenization of energy across a variety of business models, there remains much work to be done to leverage the prosumer as a core stakeholder of the new energy paradigm. Evolving our relationship with energy consumption from conservation efforts to bidirectional transactions will require leaders across technologies, public- and private-sector organizations, as well as investors, to drive digital and physical convergence that enables programmable energy.

Some of our key recommendations toward climate resilience:

- Work toward barrier-free access to new models of trading transactions in power grids for electricity produced by citizens who are also consumers (prosumers)
- Unearth and enable new business models for participants in a position to aggregate and optimize demand signals
- Align governance, regulation, safety standards and access rules on common ground and common purpose
- Develop common international frameworks relating to any and all aspects of consumer-generated electricity, with the aim of reducing barriers and democratizing grid access
- Apply tokenization and tokenomics to optimize economic value for the prosumer, taking full advantage of all the possibilities of distributed ledger technology
- Use best practices from known and established use cases to convene the alignment and development of international conventions and norms

I. Introduction: The Power of the Many

As the climate emergency intensifies, people the world over rightly wonder how they can contribute to adaptation and mitigation, and specifically how tech can be harnessed to achieve inclusive climate resilience that will limit annual planetary warming to 1.5 degrees over pre-industrial norms. Recent military action has provoked a significant price surge in fossil fuels even while disrupting global supply chains and the whole industrial complex that depends on fossil fuels. This is compounding challenges already present as a consequence of the pandemic. The global economy is in flux, as the transition to more sustainable energy production gathers momentum at a pace unforeseen even five years ago.

A key part of the accelerated transition is the rapid growth in distributed generation of electricity, principally through photovoltaic, wind and other renewable installations. The widespread adoption of autonomous power generation by citizens who both produce and consume electricity (prosumers) can be a significant asset in building climate resilience. Power grids were built and designed to link and serve large generators of electricity, leaving inherent systemic risk due to dependencies on sources that are few and far between. This risk has intensified with mounting climate disruptions which can leave a large power plant offline for days.

In this technical brief, we explore how ***Programmable Energy***, a concept developed by one of this paper's authors, Jos Röling, will play a significant role in the energy transition and inclusive climate resilience. Programmable Energy consisting of electricity generated by individual citizens, with its value assured by tokenization and recorded on a blockchain, can be convened and converged to advance the sustainable generation of renewable electricity and to assign broad value to sustainable behaviors.

The Digital Economist and the IBM Global Center of Excellence for Environment, Energy & Utilities believe citizen-produced electricity will limit global warming and lead the way to inclusive climate resilience through the adoption and application of Programmable Energy, an innovative concept that disrupts traditional approaches to electricity generation and distribution.

IBM Consulting's Global Center of Excellence for Environment, Energy & Utilities embraces an open way of working by bringing a diverse set of voices and technologies together. We collaborate closely with clients and ecosystem partners, ideate freely and swiftly apply breakthrough innovations that drive exponential impact to change how business gets done. We believe open ecosystems, open technologies, open innovation and open cultures are the key to driving change and the clear path forward for modern business and for our world. We strive to work together, create together, grow together and rethink what's possible together.

The Digital Economist has developed a "6D lens," which aligns with and advances the goals of IBM Consulting and its Global Center of Excellence. Our 6-D vision, as elaborated in our *Finding Common Ground* policy brief, is a powerful diagnostic tool to identify the challenges that need to be addressed most urgently in coping with the climate emergency. Using a foundation of Disarmament, Development and Dignity, it builds Decarbonization, Digitalization and Decentralization.

The foundational D of Disarmament (diversion of military resources from weapons manufacture toward building inclusive climate resilience in nation states) becomes D for Deployment (optimal allocation of available resources to build inclusive climate resilience) at subnational levels, including, but not limited to, private, public and social enterprises. Our 6-D lens helps focus and coalesce efforts by governments, businesses and households to achieve net-zero emissions and make choices to accelerate the transition from fossil fuels and to invest in technologies to remove and reduce greenhouse gasses.

We have the opportunity to pursue the full potential of digitalization toward improved planetary and human outcomes, particularly in applying the efficiencies of, and new horizons opened up by, digital technologies to the robust physical infrastructure needed for climate resilience. However, success will require the application and coordination of science, technology, innovation and culture. Meeting the needs of eight billion people on the globe will necessitate that we enable democratization by building strong partnerships based on trust and transparency to facilitate the use of digital technologies.

As the demand for energy rises, the delivery ecosystem becomes more complex and diverse. The number and scale of non-utility assets are increasing and becoming more dispersed. In addition to the ongoing decentralization of our physical world, decentralization refers to new approaches that can ensure optimum application of human ingenuity and technology in achieving climate resilience. The decentralization revolution in tech infrastructure holds the promise of supporting a physical and virtual infrastructure that shares common standards while respecting user preferences. This includes blockchain, distributed electricity grids, diversity in green tech and cleantech and access to new funding and investment models to take the most promising ideas upward on the technology development scale, ideally to stage 9 (ready for commercialization). Taken together, these aspects of decentralization can drive rapid experimentation, innovation and adoption of emergent best practices for at-scale deployment.

The European Union is studying the potential impact of prosumers and offers various adoption tools such as the smartEn Map, which illustrates the different "dimensions of the regulatory conditions across European countries that determine the engagement options for prosumers" As early as 2016, the EU began funding key research grants. Since 2019, the Clean Energy Package has provided a legislative framework for citizen and energy communities enabling the following outcome: "… community energy projects, mostly on renewable energy sources, have increased in number, have been incentivized and rewarded with increased acknowledgement."

Figure 1:

Figure 1: The 6-D vision is premised on two distinct but parallel layers– connected with each other in terms of their end goals. We view the actions taken to realize disarmament, ensure development, and protect dignity are integrated in the goals of attaining decarbonization, digitalization, and decentralization.

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The widespread adoption of renewable power generation is advanced by the rise of the ***prosumer.*** A prosumer is someone who both produces and consumes electricity and is connected to a smart grid, a shift made possible, in part, by the rise of new connected technologies and the steady increase of more renewable power like solar and wind in our electricity grids. A smart grid can be defined as "a socio-technical network characterized by the active management of both information and energy flows, in order to control practices of distributed generation, storage, consumption and flexible demand." These prosumers who both produce and consume electricity can be a significant asset in building climate resilience.

Power grids were built and designed to link and serve large generators of electricity, centralized hubs supplying core urban areas and often a network of towns and cities, meaning there is a centralized point of failure. IBM and its partners have already begun to posit blockchain as a means of enabling prosumers to actively participate in generating and trading electricity and playing a role in improving the capacity and resilience of electricity supply and demand.

In the US, a variety of Green New Deals introduced since 2021 are paving the way for the major budget funding aimed at the following goals: "reduce dependency on fossil fuels, increase vehicle electrification, heat pumps and other ways to reduce utility costs." While passing some of these bills has been challenging, they reflect the importance of funding the clean energy transition as well as adaptation efforts. The solar and wind energy tax credits rolled out in the Obama years have paved the way to renewable energy deployments leading to greater awareness of green versus brown energy sourcing. Across geographies, the energy ecosystem is facilitated by enabling investment into renewable energy companies, funding research, supporting innovation through various means and policy working groups.

In this paper, The Digital Economist's Center of Excellence on Human-Centered Digital Economy and IBM Consulting's Global Center of Excellence for Environment, Energy & Utilities seek to offer an actionable overview of use cases and technologies to incorporate the prosumer as a fully empowered participant in climate-resilient power generation and distribution. As we proceed with this discussion, it is important to keep in mind that "electricity is only one part of total energy use – decarbonizing electricity is only one step towards a low-carbon energy system."[4]

II. Energy transition – Background and current pressures

The energy transition is a megatrend affecting all of society. In the energy industry, major shifts from fossil fuel-based to renewable methods of generation could be seen two decades ago. Fluctuations in grid load occur due to intermittency of weather-dependent renewable energy generation using wind and solar, as well as consumption with the uptake of electric vehicles and heat pumps for residential heating.

Since the Paris Agreement to reduce greenhouse gas (GHG) emissions, governments have been subsidizing the buildouts of renewable energy sites, wind and solar. Forward-thinking entrepreneurs have also joined the cause with significant investments and testing of boundaries with incremental value creation. The carbon emission cap and trading and certificate systems for GHG emissions have accelerated the electrification of other industries as well. And since Russia launched its full-scale invasion of Ukraine, geopolitical tensions are moving the needle toward energy-independence, which is further accelerating electrification.

The grid we all rely on every day for almost all aspects of life is the result of a 100-year engineering effort to build the biggest man-made system of systems. The grid of today is the future of sustainability.

In Europe, each national or regional authority has installed a state-owned system operator that orchestrates the market for its regional network

Figure 2

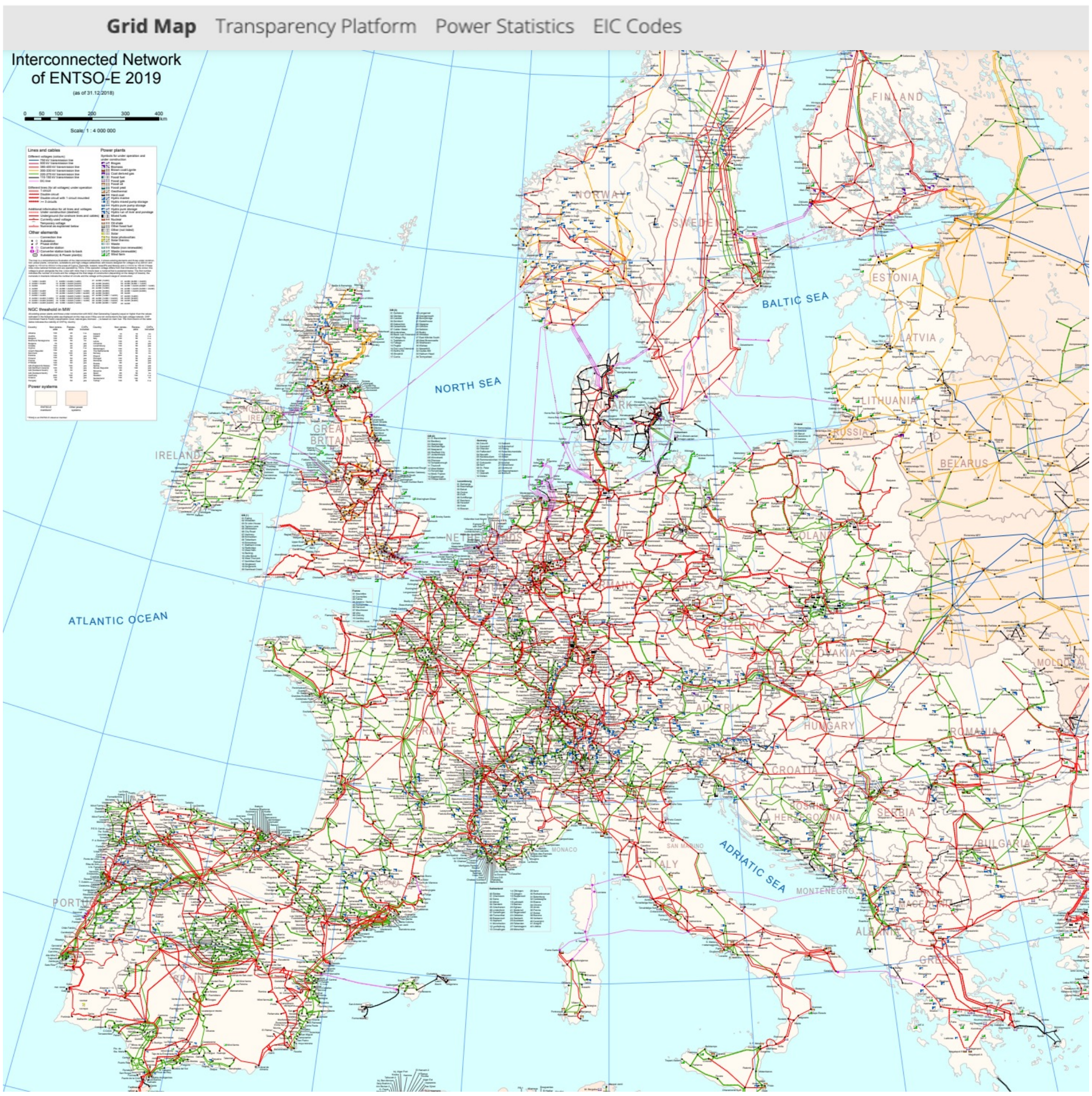


Figure 3

Image Source: Cybersecurity and Infrastructure Agency

given the constraints of the grid in order to ensure all components work together. In most countries, the energy grid is classified as a critical infrastructure similar to finance, water, communications or transportation.

Piecemeal development and political decision-making in the past have led to complex market setups and a centralized system of operations of this critical infrastructure, including investments from a key period of transformation, development and amplification related to postwar reconstruction and the international development agenda. Where some countries have opted for full market setup, due to popular belief in the '80s that "there is no alternative," others are developing integrated companies and are slowly adopting decentralization decades later.

There are multiple challenges/opportunities we need to address in this old construct, which have led to new grid requirements:

1. New modes of energy generation
2. Bidirectional energy flows
3. Net increases in energy consumption
4. Shift in load patterns

These new grid requirements are also demonstrated in the figures below.

Figure 4

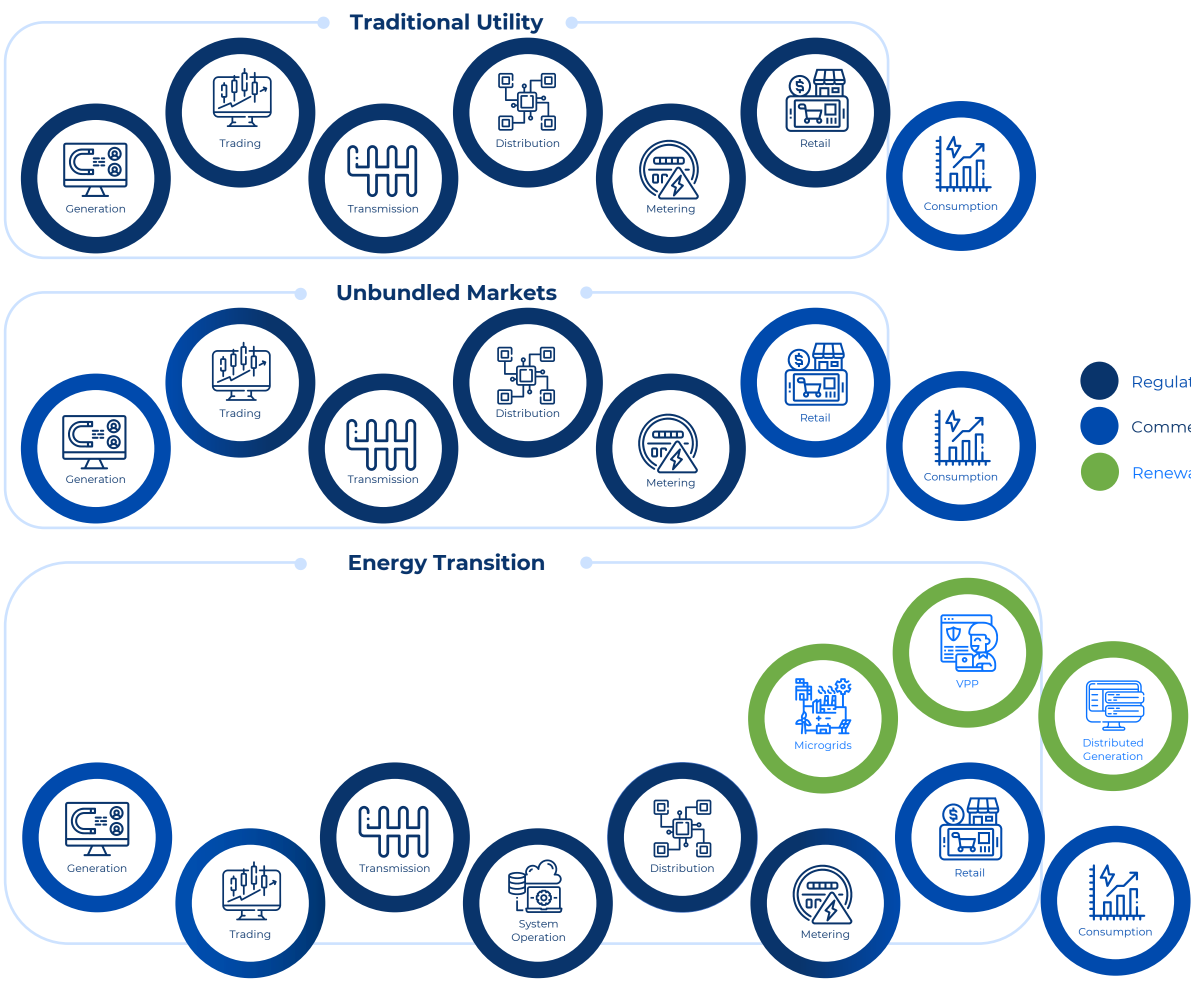


Figure 5

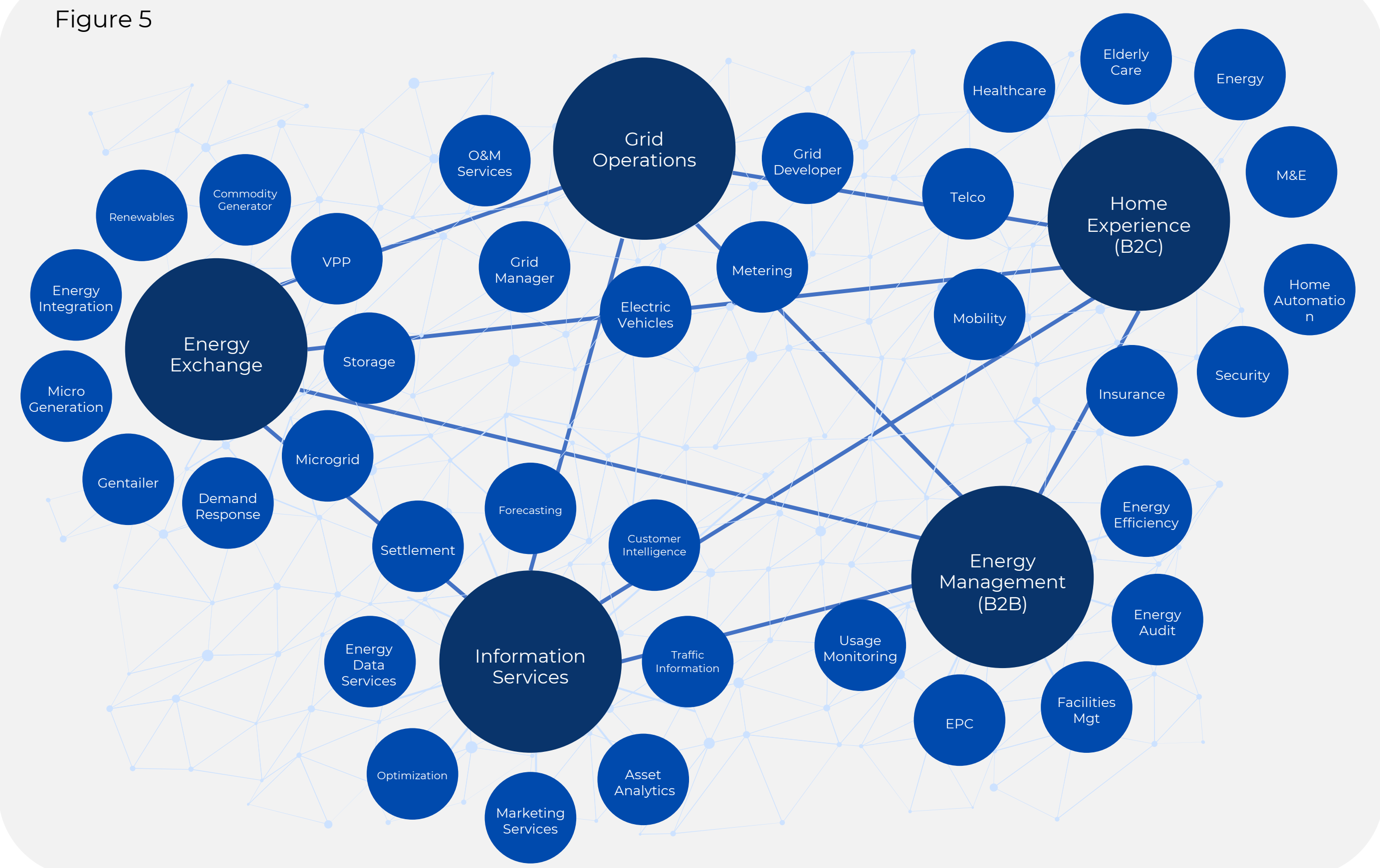


Image Source: IBM, The Energy Integrators

The advancement of exponential technologies such as blockchain, Internet of Things (IoT) and artificial intelligence has given rise to a new paradigm and capacity to support novel models. These, in turn, create opportunities for the development of funding models and energy markets supported by microgrids that enhance the role of the prosumer. “Blockchain will give utilities less control than legacy systems,” said Christopher Irwin, a program manager with the U.S. Department of Energy, “but it will make the system work better.” Irwin compares the transition to the advent of anti-lock braking for automobiles, “… which gave drivers less control of their brakes, much to their benefit.”

Our thinking is also informed by thought leadership from Jeremy Rifkin, author of The Green New Deal, who indicates that “this next phase of infrastructure modernization is rooted in the convergence of 5G communications, a renewable energy Internet (clean technologies and smart grids), and a digitized mobility and logistics platform (autonomous electric vehicles, artificial intelligence, and the Internet of Things),” which constitute the unfolding of the Third Industrial Revolution.

New modes of energy generation

One aspect of renewable energy commonly misunderstood is the lower density of generation, in that we need more surface area to generate energy compared to fossil fuel-based sources. From a grid perspective, there is a need for more connections to distribute power, which will inherently create flexible energy flows through the grid. In this scenario, the advancement of technologies such as battery storage capabilities are critical to optimize generation from new modes of energy generation. According to the International Energy Agency (IEA), renewables are expected to account for “almost 95% of the increase in global power capacity through 2026,” and represent “yet another sign that a new global energy economy is emerging.”

Bidirectional energy flows

Distributed generation, even at the micro level such as roof-top solar, impacts energy flows through the grid. Some segments experience a bidirectional energy flow due to daily or seasonal weather patterns. The shift from unidirectional to bidirectional has significant ramifications on grid settings for safety and voltage. E.g. simplified in a unidirectional grid, the voltage is manually set high to accommodate anticipated voltage drop dependent on the length of cables and wires. Optimal bidirectional energy flow from local generation would enable a high voltage consumption coupled with a low voltage for infeed.

Net increases in energy consumption

As residential use of fossil fuel is replaced by electrified devices and appliances, such as electric vehicles, there will correspondingly be a large increase in the demand for electricity. Also, many industries are electrifying to meet their ESG-related emission goals. Some of the industrial solutions being deployed are very flexible, such as the new hydrogen electrolyzers that can ramp up and down instantaneously, while others require a significant and consistent base load. Nevertheless, the urgency has never been more evident, as a “new IEA report sees a 5% rise in electricity demand in 2021 with almost half the increase met by fossil fuels, notably coal, threatening to push CO2 emissions from the power sector to record levels in 2022.”

Figure 6

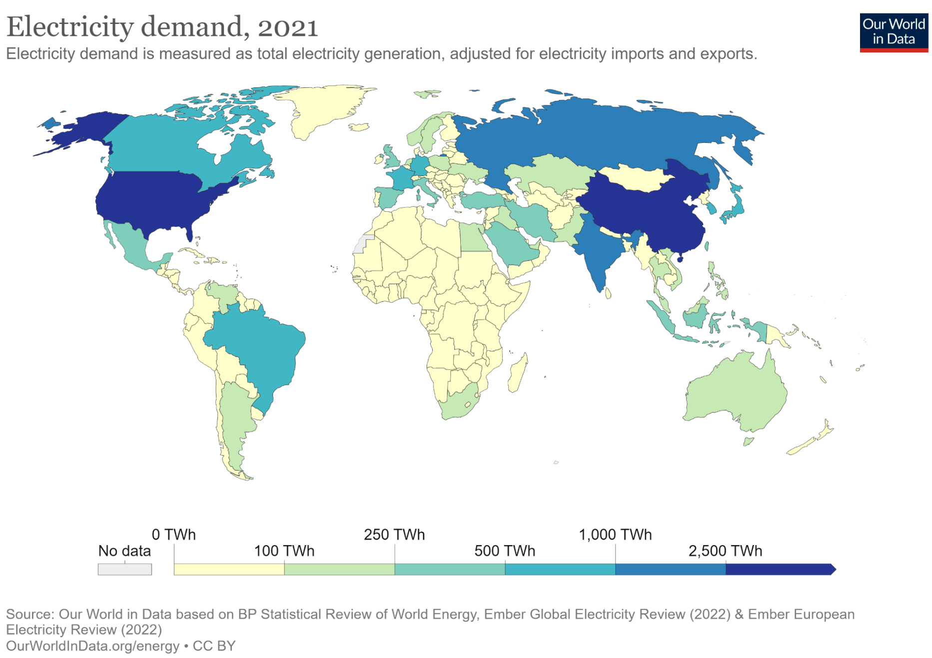


Figure 7

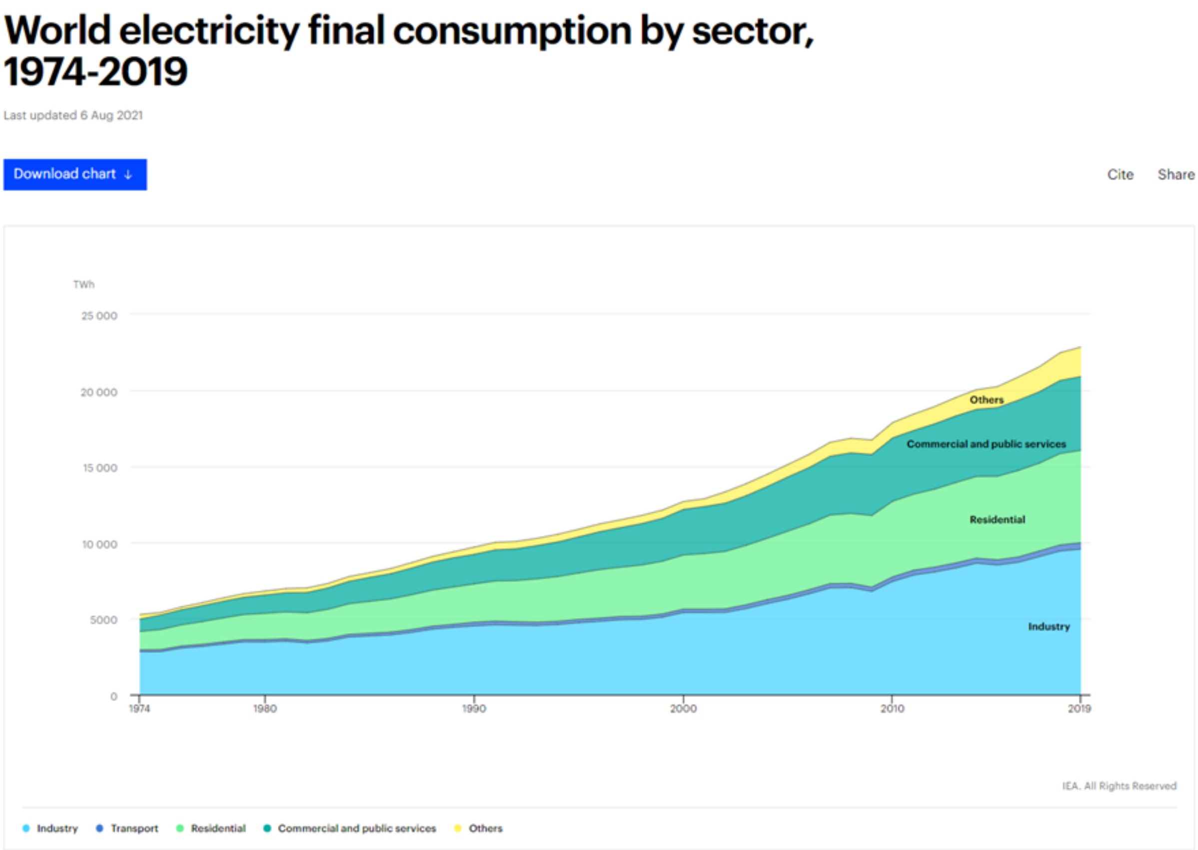


Image Source: International Energy Agency

Emerging market contexts:

Figure 8:

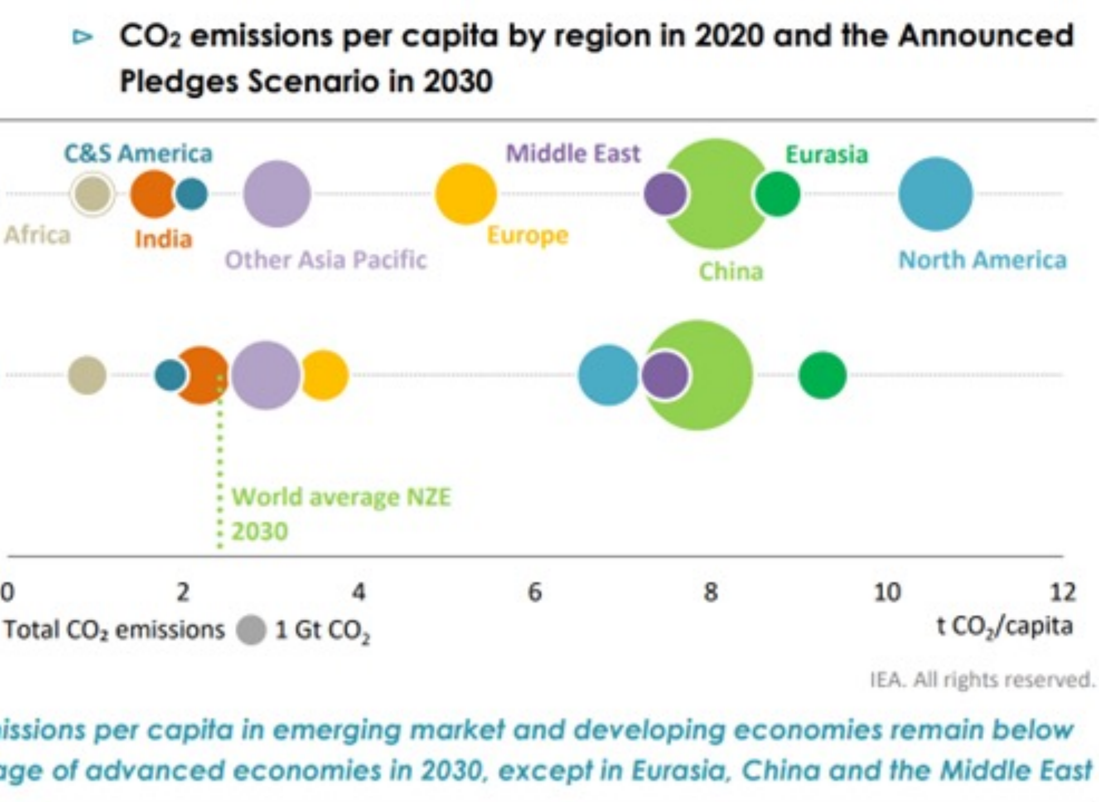


Image Source: International Energy Agency

As highlighted by German Chancellor Olaf Scholz in his closing remarks at Davos 22, citizens of all parts of the globe expect the same levels of prosperity that leading nations have demonstrated is possible. According to the IEA, electricity demand is projected to grow rapidly in emerging markets and developing economies through 2030. This reflects increased uptake of industrial electric motors and rising levels of appliance ownership rather than large-scale electrification of new end-uses such as transport. However, predicted per capita CO2 emissions in emerging markets and developing economies (excluding China) are less than half of the advanced economy average in 2030, given the announced pledges scenario (APS). The IEA estimates that 770 million people worldwide still live without access to electricity, mostly in Africa and developing countries in Asia. It also says the impact of the pandemic on household incomes has weakened the ability to pay for electricity. Energy poverty is exacerbated by political decision-making, which has traditionally focused on costly, large-scale and centralized infrastructure that is often fossil fuel-based. This is an important consideration as the times of the few sources providing for the many are ending. It is key to recognize the prosumer as an important piece of the puzzle to support equity and the journey toward economic prosperity in emerging regions.

Shift in load patterns

Given the rate of replacement of vehicles with internal combustion engines (ICEs) with electrical vehicles (EVs) in North America, Europe and some parts of Asia, load curves are expected to be stressed beyond current grid capacity due to post-work-hour commute charging load.

III. New normal

Challenging the assumptions

The demand-led dynamic of the energy grid we have taken as the norm for the last century is no longer viable. Physical grid connection limits, designed with sufficient headroom, are no longer sufficient. The "all you can consume" construct has resulted in a hockey stick curve in energy increase, which our grids can no longer support. Now that we are collectively reaching the limits of this way of operating and taxing the system, we realize there is no silver bullet or quick fix. Nevertheless, we have advantages: advancements in technology can enable new ways of solving the problem. Projects that have demonstrated potential include the crowd balancing platform pioneered by **TenneT**, which leverages consumer-invested batteries (in their EVs) as a resource for grid balancing. In this scenario, a 3-hour charging session is impacted by only 10–15 min. These kinds of use cases sustain customer expectations and test the boundaries of the customer experience while contributing to system operation optimization. This is an example of a more sophisticated use of the grid, yielding some level of control on the part of the consumer for the common goal of grid stability.

Further support for participatory solutions can be found in *Smart Grids the Human Scale,* which describes the social impact motivations of the energy transition. In the work, R. Smale notes that with "the implementation of smart metering and monitoring technologies, domestic energy practices are brought under scrutiny and are reformed in light of (digital) information about those practices and the wider energy system." Through different workshops facilitated across diverse prosumer groups, the author notes that prosumers are very well able to articulate their concerns, motivations and values with respect to different ways of organizing and operating energy platforms – seeking to embrace the risks and opportunities of becoming energy co-managers. Despite the varied behavioral approaches to household energy consumption and management, this study concludes that "prosumers are an (if not the most) important factor of the new emerging energy paradigm." To support this new paradigm, new architectures and technology solution patterns are emerging, enabling the development of collaborative approaches and business models, leveraging the use of blockchain in all major segments of the energy sector.

Figure 9:

Energy Use Cases for Blockchain

Image Source: IBM

The adoption of 4G/5G wireless communication by original equipment manufacturers (OEMs), to establish connectivity with products and services being used by their customers to understand, manage and optimize behavior over time (asset performance management) is outpacing the technology adoption of utilities and grid operators. New collaboration platforms such as those provided via blockchain can be used to automate the integration of advanced smart devices for utilities to secure, predict, monitor, influence and control the energy demand and supply with respect to the local grid state.

As an example, in the last four decades the transmission system operators (TSOs) in Europe collaborated to share best practices and were supported by the European Commission in creating a harmonized role model for the energy industry to establish a single European market. There is most likely no simple and risk-averse solution to replace the European harmonized role model. Transformations within this model have to be a gradual shift that can be installed, validated, verified, stress tested etc. on an ever-increasing scale, for all to build confidence that the new way of working will not jeopardize grid stability.

Figure 10:

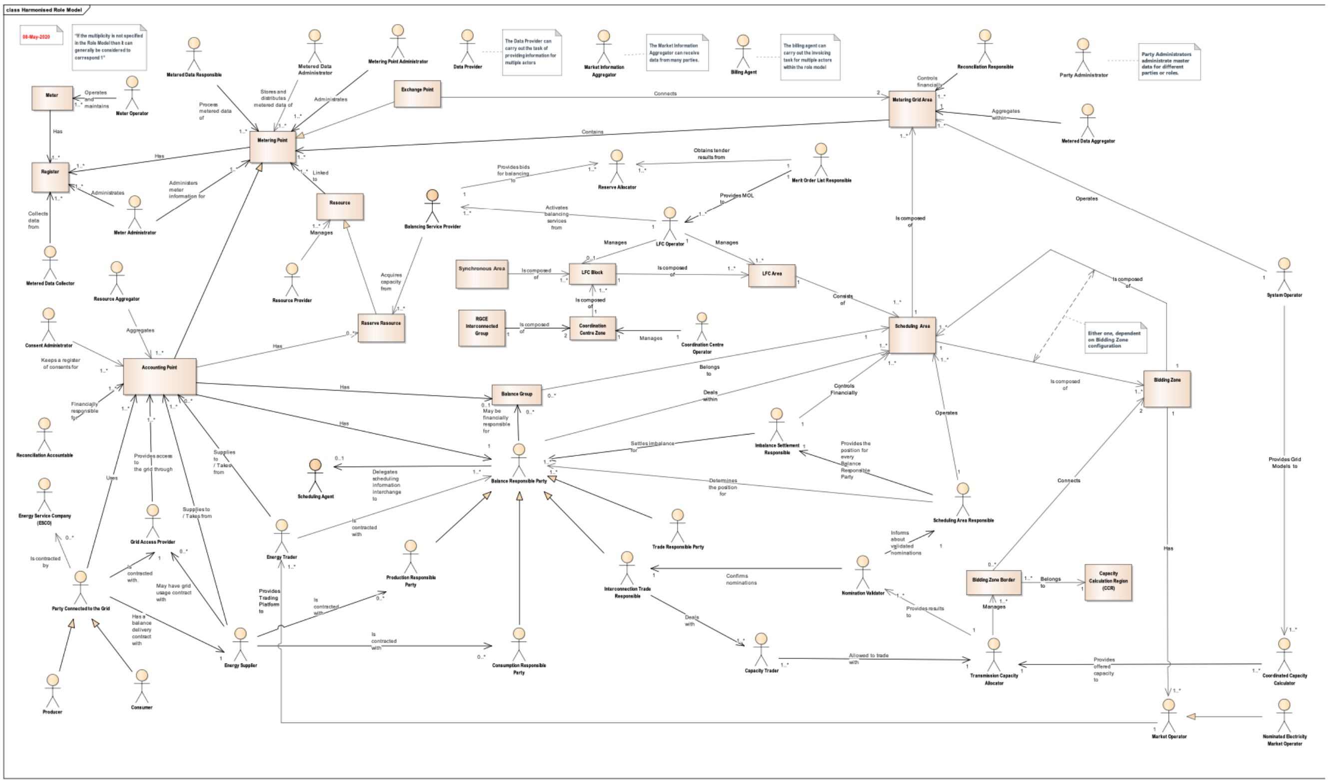


Figure 4: The Harmonised European Electricity Market Role Model

Image source: European Association for the cooperation of transmission system operators for electricity

In the US, the image below showcases the ways in which renewable energy is being integrated into the grid and complementing generation by the transmission system operators (TSOs).

Figure 11:

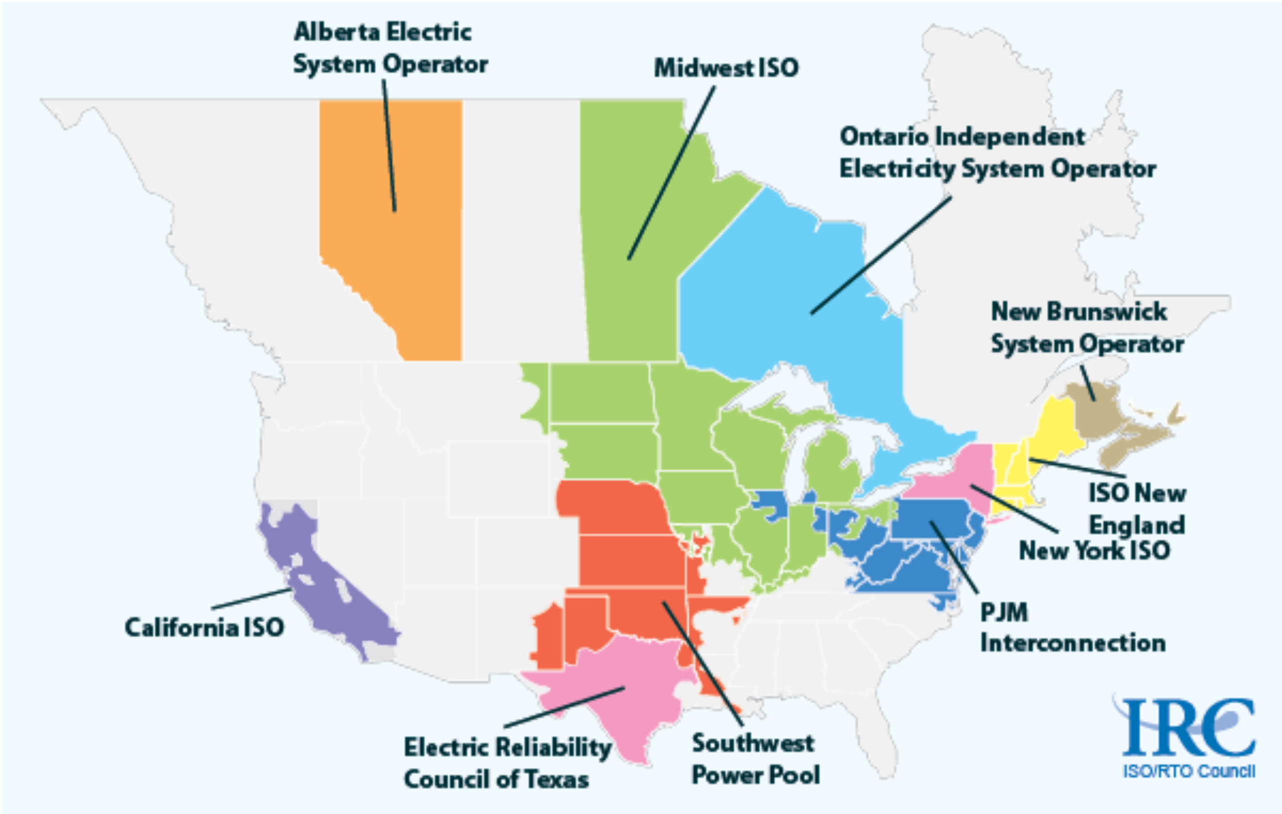


Image Source: Independent System Operator/Regional Transmission Organization Council

Figure 12:

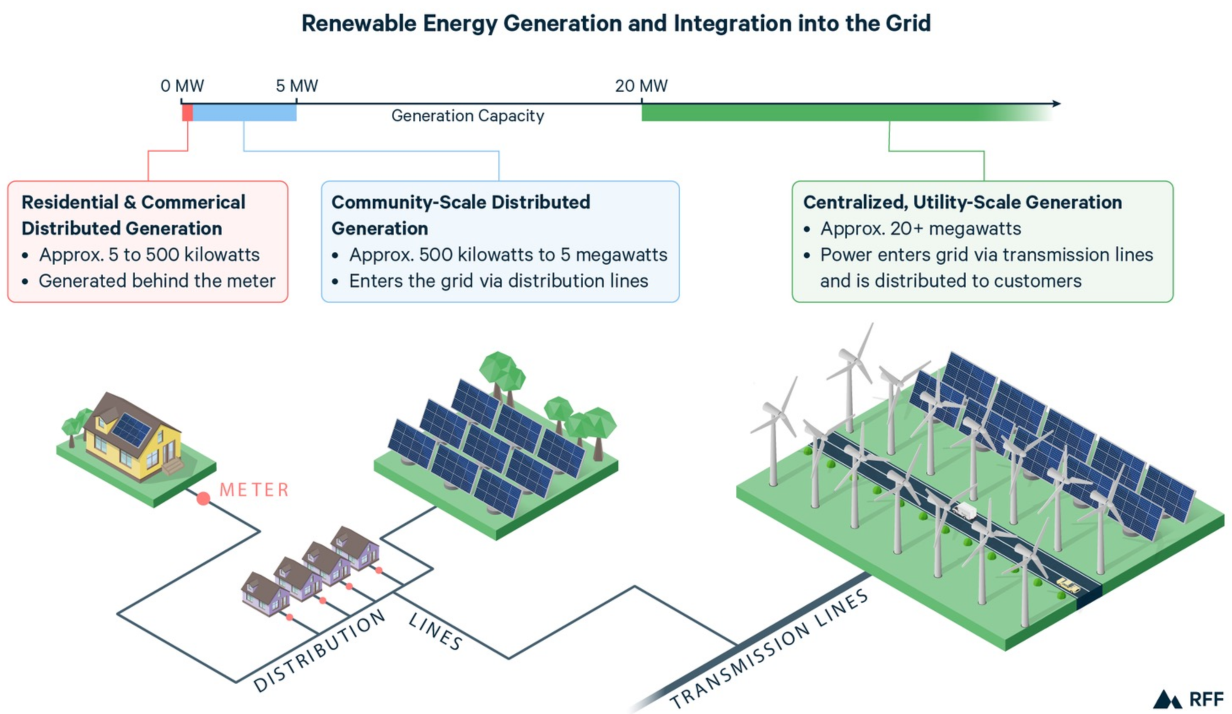


Image Source: Resources for the Future

IV. Business regulation and technology landscape

This section is focused on developing a broad but functional understanding of how tokenization, supported by convergent technologies, is enabling a variety of energy use cases. The following is intended for an audience including, but not limited to, students, entrepreneurs, regulators and those seeking to leverage emerging technologies for new business models or who might seek to broaden their fundamental and technical understanding of how these new market models are being facilitated. We advise those interested primarily in the landscape of latest energy use cases leveraging emerging technologies to skip ahead directly to the last section titled "Use Cases."

IBM has partnered with several organizations in their implementation of energy projects to leverage and optimize the concurrent convergence of technologies such as Internet of Things (IoT), blockchain, analytics, automation, 5G and artificial intelligence (AI). Many successful use cases have emerged and case studies in production have been promising. Further, we have observed early examples of how these technologies, when combined, are driving exponential results.

For example, as discussed in IBM's publication, *The Green Light*, "Blockchain helps us to open up access to small, distributed energy resources. It also enables viable aggregator business models, once the relevant policy and regulation is in place. But what is perhaps most revealing is how it supports the democratization of energy. It enables consumer choice and fairness in access to markets, and empowers participation in the energy transition." The graphic below shows the various key stakeholders and technologies that are enabling the decarbonization of electricity generation.

Figure 13:

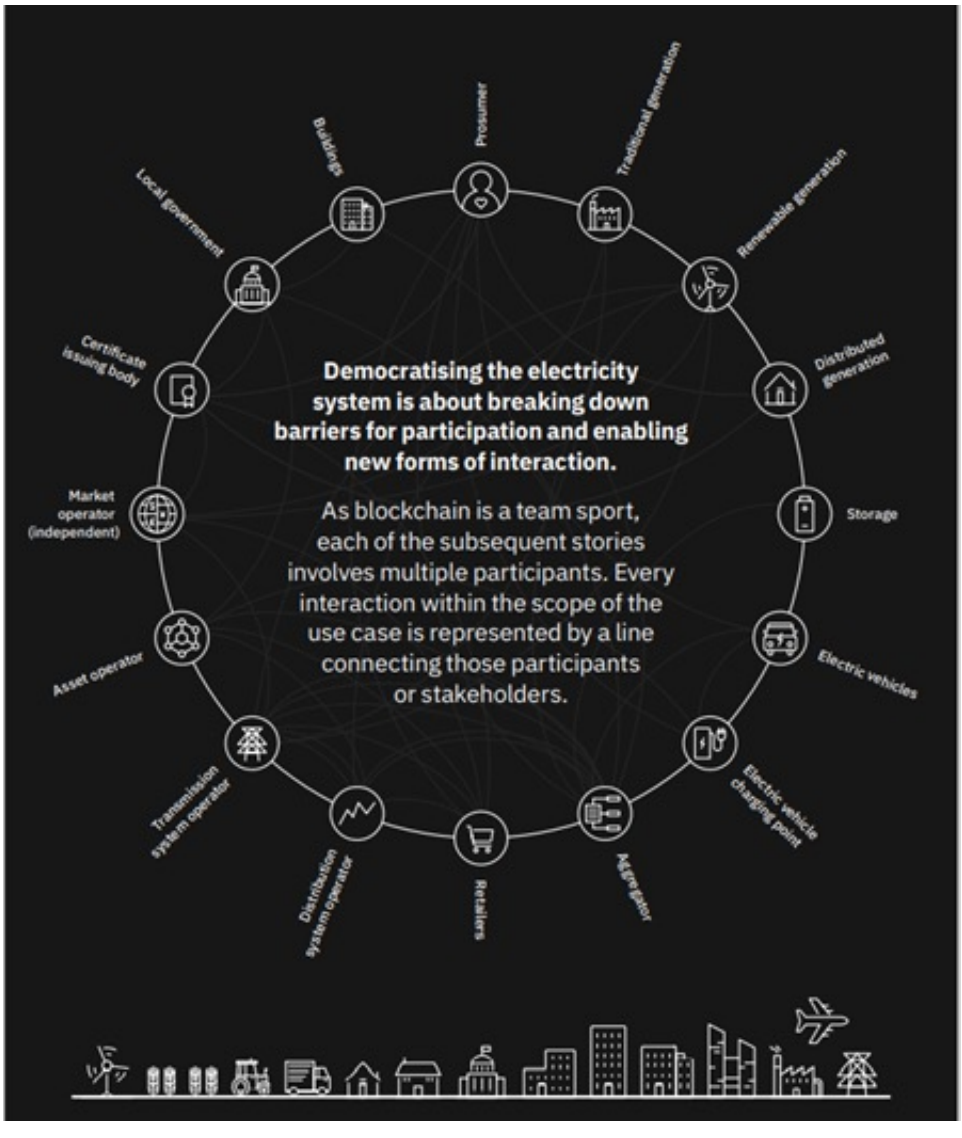


Image Source: IBM, The Green Light Report

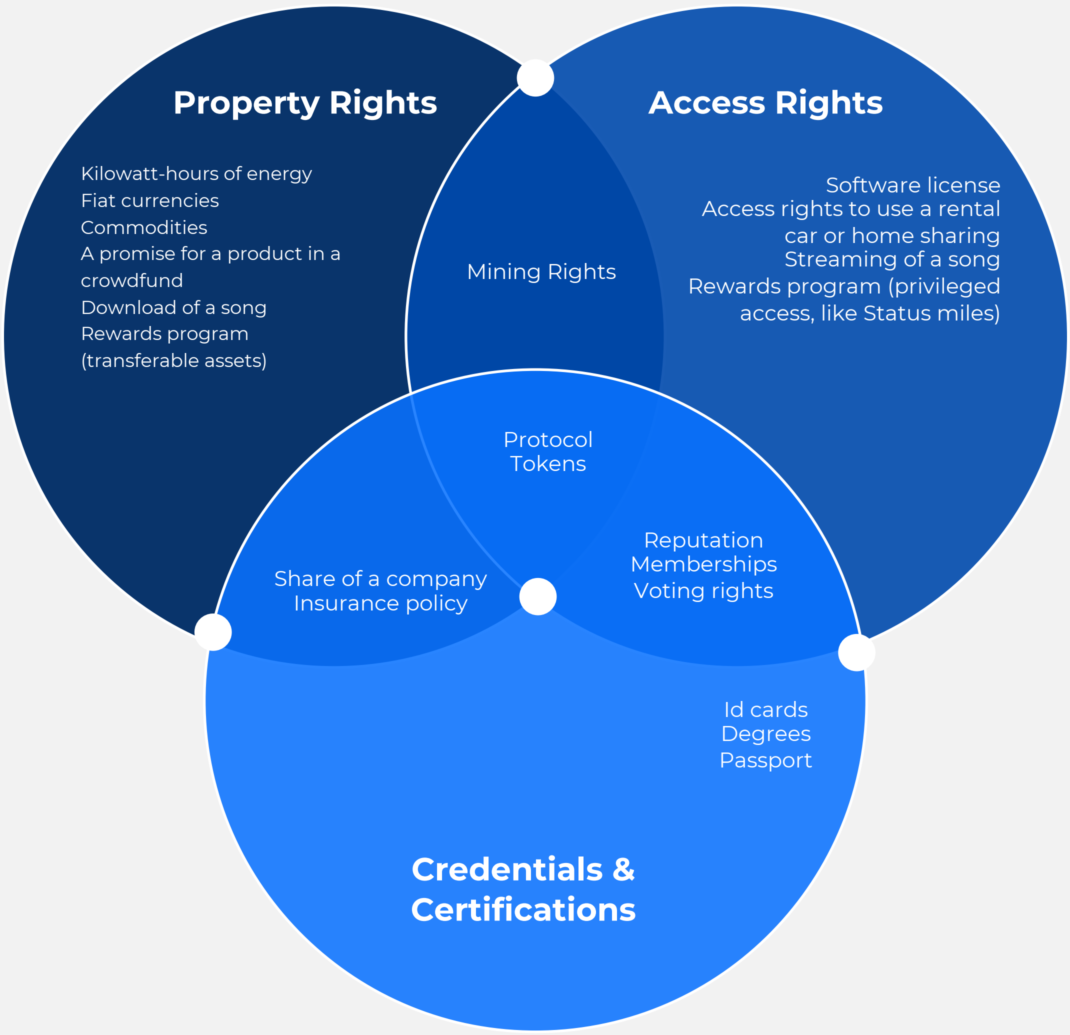
Given the potential applications of blockchain, it is then helpful to explore what tokens are and how they might be applied to creating new business models. Shermin Voshmgir offers the following thoughtful perspective: “Tokens are the atomic unit of the Web3 and are collectively managed by a distributed ledger. They can be issued with just a few lines of code with a smart contract. Token contracts are rights management tools that can represent anything from a store of value to a set of permissions in the physical, digital, and legal world. They might affect the financial world similar to how the Internet affected the postal system.”

Token technology, along with the underlying smart technologies (IoT, AI and analytics), allows us for the first time to create digital assets that can be exchanged between market participants in a manner similar to how physical goods are exchanged. Concurrently, the advancement of renewable energy generation and storage technologies enables us to complement the traditional capacities of the grid, including developing independent microgrid systems and a variety of energy aggregator business models. These new business models establish the market for renewable energy developers, increase climate resilience of aging grids and reduce our collective carbon footprint.

Figure 14:

Rights Perspective

Tokens can represent different rights



Setting up a blockchain-based tokenized system requires an assessment of the legal, engineering, policy and technical landscape. Through the use cases we will explore in this paper, we will discuss how various models are able to leverage the nascent yet increasingly open regulatory landscape to effectively deploy these energy tokenization business models.

a) Assessment framework

To evaluate whether an energy project can benefit from tokenization, it is important to assess landscape readiness to understand whether the enabling conditions exist. This, of course, starts with technology and understanding whether there are pools of distributed energy or flexible demand nodes that could be monetized either by trading or by reducing the dependence on fossil fuels. Then it is necessary to leverage the set of technologies described above (IoT, 5G, analytics and blockchain) to efficiently capture and tokenize these pools as transferable assets. At this point, it becomes important to understand whether the regulatory environment permits the exchange and trading of these assets and how to run the project in compliance with the various regulatory requirements. If the regulation and policy framework looks promising, it is imperative to have the financial infrastructure in place to monetize these assets through an ecosystem of market players. This can be facilitated by digital wallets among existing market participants willing to purchase the excess energy or peer-to-peer (P2P) trading platforms, while maintaining the affordability of energy costs for purchasers or ability to satisfy their carbon offset goals.

The figure below is a visual representation of the enabling environment required to enable successful blockchain use cases in the energy sector. There are different types of technologies that can be leveraged synergistically, and it takes a range of on- and off-grid assets, including databases, which can support rebalancing for the grid's needs. The financial incentives and mechanisms listed help support the financial viability of these models while ensuring the markets provide value to all stakeholders. Through these market transactions, resilience, affordability and sustainability are key performance indicators.

Figure 15:

Image Source: IBM and TDE

b) Packaging energy

Energy and finance are considered critical infrastructure for most economies, and are accordingly heavily regulated. Tokenization can have a positive impact and remove regulatory barriers. L. Lolkema from Afdeling Marktfacilitering describes tokens as a new way to package energy. Different from the grid's physical continuous flow of energy, thinking of energy as a package creates the potential for market participants to transfer and trade kWh in the market. The energy token allows energy trading either ex ante – for trading in the spot, futures or balancing markets – or post ante between counterparties trading excess generation with demand. This means the current way of selling energy can shift from the traditional model of power purchase agreements by bundling energy, either by consumption (e.g. community renewable energy assets), flexibility (e.g. EV charging) or appliances (e.g. buy hot water as a service). Energy tokens enable business models and use cases to track sustainability and offer green signals, achieve net zero targets through the issue of carbon certificates and facilitate efficient allocation, clearing and settlement of energy units. It is this transition that allows customers (consumers) to become energy-responsible parties (prosumers). In order to stimulate this transition, leaders and innovators in the energy marketplace should use token taxonomies that are non-platform-specific, which will allow for an outcome- and impact-based digital framework. Gradual introduction of these tokenized models should accelerate the energy transition, ensure affordability and stabilize energy supply.

c) Core elements of a blockchain token model and various market roles that tokens can play in the energy transition

Smart meters or calibrated IoT devices serve as crypto anchors for minting, the virtual equivalent of generating currencies. Energy tokens are exchanged between market parties to reflect supply and demand. Clearing is done when supply meets demand – allowing allocation and clearing process based on our token allocations for instant settlement. Tokens are held in wallets. On the generation side, prosumers and generators can hold wallets with different types of tokens based on the type of generation (e.g. renewable energy, fossil fuel and battery). On the demand side, we could envision a wallet for each energy consumption device (e.g. home, EV and each public charger). This creates a new model

Figure 16: Programmable Energy token use cases

Image Source: IBM

for the electricity consumption ecosystem. This transition of energy packaging and tokenization holds the potential for energy consumers to become active economic participants in how energy is produced, valued and stabilized. Prosumers can become proactive to achieve net zero targets, creating new viable business models for energy optimization, wealth generation and inclusion and augmentation of grid resilience.

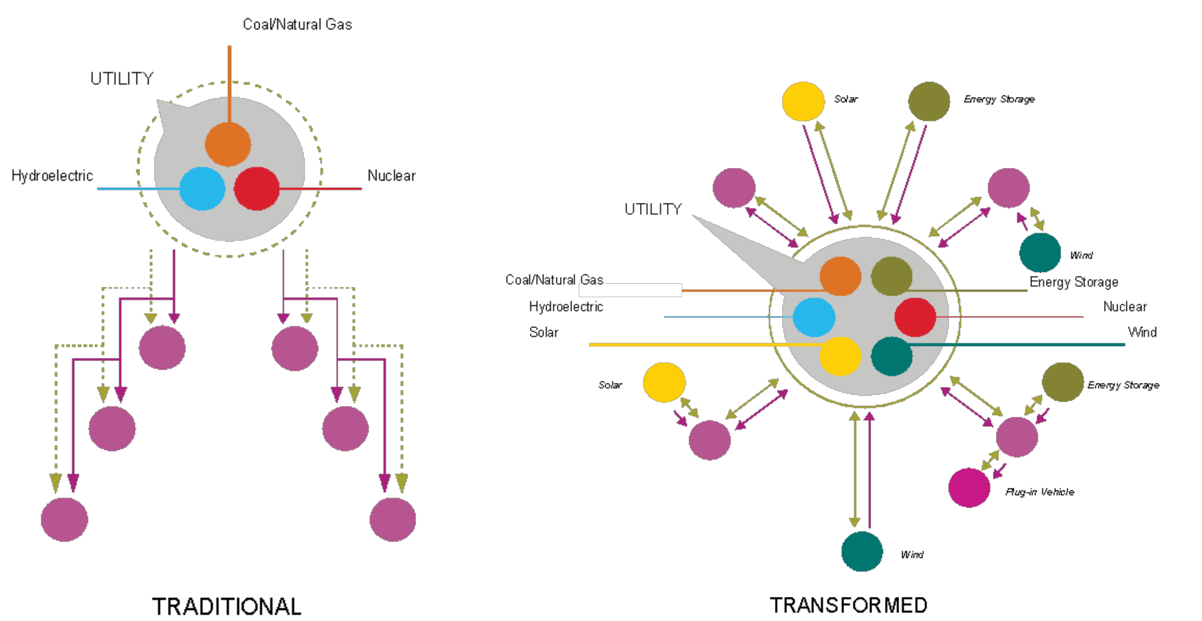
Several forms of tokens have emerged, facilitating new investment models. First of all, tokens facilitate the allocation mechanism to trade packaged energy. From another perspective, tokens can represent renewable energy certificates, guarantees of origin (GOs) or offsets that support the reduction of carbon footprint from net polluters. Tokens can also be created to track any sustainability-related outcome such as air quality, creating new markets for investors and corporations seeking greater positive environmental impact. In addition, tokens enable the financing of these new energy use cases – providing new community ownership models of renewable energy assets, offering opportunities for fractional ownership, efficient clearing, settlement and insurance claims.

New grid requirements

The incremental smart grid projects of this century and traditional engineering best practices will not keep up with the pace of change imposed on the grid. The transformed grid of the future needs to become bidirectional and more resilient, while supporting a more intermittent load.

The future market structure resembles a more demand-driven grid model where large generators, in addition to stored energy and unused residential energy, are distributed through new market models to meet changing demand. As discussed above, blockchain powers this new distributed generation model – by leveraging both the physical grid as well as the smart grid – and generates new investment models, promotes energy access and boosts the reliability of the grid. It is the convergence of these innovative technologies that offers a more sustainable and responsible model of place-based and distributed energy generation and distribution.

Figure 17:



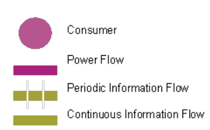


Image Source: IBM Institute of Business Value

V. Use cases: Deploying token technology for real-world energy market applications

Over the last decade, we have seen incredible progress in renewable energy technologies to offer improved reliability and a path toward greater sustainability and innovation in energy generation. This is good news, as the clear shift toward clean electrification to meet sustainability and decarbonization goals results in ever-increasing demand for affordable, reliable, sustainable energy. However, enabling clean electrification at scale for consumers and businesses will require our leaders to collaborate and rethink how energy is delivered. By incorporating renewable energy producers into the matrix of grid suppliers through net metering and monetizing carbon credits, sustainability can become integrated at a granular level while flipping on the light switch. In emerging market rural environments where grid infrastructure may not exist, the fast-growing adoption of mobile technologies offers new opportunities to rebuild energy infrastructure, leveraging mobile applications as a way to pay for increments of energy use. In the backdrop of the prosumer emerging as a dominant figure of the energy transition, energy providers such as the Royal Dutch Shell are finding market opportunities in the simultaneous development of renewable energy to complement fossil fuel-based generation in order to accelerate the transition to net zero emissions.

Over the last few years, we have seen a proliferation of innovative use cases leveraging different blockchain technologies to demonstrate the economics of energy token models.

Delivering these use cases at scale across legacy and/or mobile infrastructure will require orchestration across a reimagined energy value chain. Throughout these use cases, we observe that blockchain serves as the convening element among innovations of physical technology and the integration of new providers in existing value chains. Successful use cases reflect innovation around energy technologies and the robust interplay of grid assets with emerging technologies that leverage financial investments and/or regulatory incentives.

The blockchain-based, energy-focused use cases discussed below are well past proof of concept, beginning to demonstrate potential scalability across managing asset lifecycles, leveraging energy storage and grid balancing, trading in spot and futures markets, accelerating retail investment including digital green bonds, issuance of new assets (including community and alternative ownership) and managing energy access and usage mandates. For example, Equigy's crowd balancing platform aims to leverage consumer-invested batteries as a resource for grid balancing and strives to become a marketplace for TSOs and DSOs in Europe. Solstroem enables off-grid solar projects to access the carbon market, supporting the rollout of solar energy to the less privileged in off-grid rural environments with additional benefits of reducing deforestation activities, while also allowing access to mobile and banking services. In Africa, Irene Energy has successfully applied a multicloud deployment strategy to accelerate access to electricity and establish the back-office infrastructure for electricity roaming services. Power Transition in the UK is an innovative microgrid management platform that enables peer-to-peer energy trading that will begin granting consumer homes the ability to establish a local grid that can operate independently, creating a marketplace between residences during times of excess or power outage. Restart Energy Democracy (RED), an independent EU electricity and gas supply company, operates a decentralized energy supply platform to award green energy certificates to consumers of renewable energy.

Figure 18: Use case legend

Use Cases	Storage	Grid Management	Trading	Retail	Generators	Metering
Equigy						
Evercity.io, Blockchain Triangle						
Restart Energy Democracy, Power Ledger and We Power						
FlexiDAO						
Irene Energy						
Solstroem						
Power Transition						

The use cases are by no means comprehensive, but rather an overview that seeks to illustrate the potential of blockchain for energy provision and remuneration. For certain use cases, such as Irene Energy and Power Transition, our overview focuses on technical design and use of blockchain protocols. For the others, we look at the business model design with the robust links between market participants seeking to have impact around the UN Sustainable Development Goals (SDGs).

Blockchain is also enabling new financial models for local renewable energy from carbon credits, peer-to-peer and the potential for aggregation into investing mechanisms and green bonds. For example, The Green Digital Finance Alliance's report on Green Bonds and debt products observes that blockchain technologies can enable the aggregation of smaller-scale renewable energy projects into investable and traceable financial instruments whose efficiencies are tenfold those of traditional mechanisms. These findings were expanded in the Bank of International Settlement's Project Genesis report and pilots. In addition, organizations such as Evercity.io and Blockchain Triangle are actively building platforms automating issuance, management and impact monitoring including aggregated small-scale renewable energy projects.

Irene Energy

Irene Energy realized that despite adequate infrastructure, many homes in Africa lacked access to electricity due to the required high upfront capital. In fact, nearly one billion people in Africa lack access to electricity. Irene Energy aimed to create a cheaper and more flexible back-office infrastructure for energy service providers. Utilizing the Stellar blockchain, Irene Energy was able to connect with IBM to bring blockchain-based access to electricity to rural parts of Africa. By working together, the companies were able to reduce the cost of connecting homes to power. Within a few years, they spanned five African countries and 50,000 users. It became feasible through blockchain for individuals to contribute a portion of their weekly wage into a community fund until they had built up enough money for a new grid connection. It also allowed energy roaming in which people may, for instance, charge their phones at a friend's home and pay for the power themselves, ensuring that costs are fairly shared.

Talium, Irene Energy's consulting partner, utilized the Stellar blockchain because of its low transaction cost and utilization of simple smart contracts. Through Stellar, it was able to leverage blockchain authentication with public key cryptography allowing Irene Energy's platform to look up users' private keys whenever they submit a transaction. Another key factor was that Stellar doesn't just serve as a ledger with account balances and payments, but also includes a native decentralized exchange with global order book and matchmaking that allows on-ledger orders, secured by the Stellar Consensus Protocol (SCP), as a simple addition.

Cryptographic key management is foundational to the security of digital money. Public keys work similarly to email addresses in that you can provide them to anyone. Counterparties can send data in but can't take data out. Private keys on the other hand operate like passwords to your safe: the person in possession of these keys has control of the entire content. When trading, centralized exchanges such as Coinbase or Binance store the user's private key on centralized servers, which have historically been prone to hacks. Comparably, on networks like Ethereum, decentralized exchanges (DEX) are not built at the protocol level but rather on a secondary framework that is built on top of the existing system having to store funds through often sophisticated smart contracts. Unfortunately, these have also recently seen their share of high-profile exploits. The Stellar DEX solves these issues by enabling noncustodial key management for users and by providing a secure native DEX implementation.

Since Stellar authenticates users through public key cryptography, Irene Energy needed the ability to look up users' private keys after they submitted a transaction. As a result, it had to come up with a way to prevent both the employee and the customer from seeing the private key at any moment during the transaction. Using a platform designed by IBM and Fortanix, Irene employed a solution called "IBM Cloud Data Shield," which helped accelerate development by 6 months. Being built on top of the IBM Cloud Kubernetes, it is able to handle hundreds of thousands of users while scaling seamlessly. The Data Shield enabled Irene Energy to containerize its apps and run them on SGX-enabled bare metal worker nodes using IBM Cloud Kubernetes Service. Instead of forcing businesses to build their apps specifically for the SGX, IBM Cloud Data Shield converts the code to be compatible with the platform's features.

Finally, IBM Cloud solutions offered an open architecture that allowed Irene Energy to benefit from a multicloud deployment approach. As a result, data moves freely between the various microservices that make up the application, regardless of whether they're running on a different underlying platform.

Solstroem

Danish-based Solstroem has developed a finance business model for off-grid solar by leveraging carbon markets targeting specific developing and emerging countries. Solstroem is a Danish technology company and carbon avoidance program which allows off-grid solar projects to access the carbon market. The issued carbon credits are annotated with a timestamp and a geotag, making them transparent and trusted. The system and its underlying methodologies are backed by a thorough third-party verification by the membership group Det Norske Veritas (DNV). Solstroem enables off-grid solar projects to access the carbon market, supporting the rollout of solar energy to the less privileged in off-grid rural environments with additional benefits of reducing deforestation activities, while at the same time providing access to mobile and banking services.

Evercity.io Digital Bonds and Blockchain Triangle

Organizations such as Evercity.io and Blockchain Triangle are actively building platforms automating issuance, management and impact monitoring including aggregated small-scale renewable energy projects. A key element of these models is the connection of smart meters and IoT devices into the digital securitization process, delivering speed, efficiency and transparency to all stakeholders.

Evercity allows issuance of green, SDG-linked debt and carbon credits on the blockchain with tenfold speed, transparency and traceability. The real-time impact monitoring enables users to connect the interest rate to physical impact performance to boost the confidence of investors. Evercity further works to reduce the operational complexity and issuance cost by process automation. Blockchain Triangle offers a digital security issuance platform – a marketplace that connects big data and securitization on one chassis, connecting issuers and investors to allow for easy and transparent access to climate and infrastructure projects.

Equigy

Currently, in its home markets, Equigy is actively engaging in discussions with TSOs and DSOs to implement its solution. For example, Swiss TSO Swissgrid, together with Zurich's DSO EWZ, has already developed the first TSO-DSO coordination project (RR product). The pilot research project was launched in the second quarter of 2021, and is likely to be completed by the middle of the second quarter of 2022.

This project focused on identifying how flexible energy sources and consumers – such as domestic battery storage systems, heat pump technology or electric vehicles – can be used efficiently to provide ancillary services for the transmission or distribution grid. The aim here is to harness these available flexibilities in the grid for the service that brings the greatest benefit for the security of the entire system.

Equigy's role is to guarantee participants in the project a secure and transparent exchange of data and information. Equigy's blockchain technology also offers the opportunity for the extensive automation of the business processes arising from the collaboration between DSOs and TSOs. This will result in lasting improvements in coordination and efficiency.

FlexiDAO

In the Netherlands, FlexiDAO, Eneco and CertiQ will be testing time-based green electricity in the Netherlands to provide certification in the future and make possible a real decarbonization of the electrical grid. The pilot project involves a digital link between the 120 MW Princess Amalia Wind Farm and Eneco's 12 MW electrode boiler connected to The Hague's Ypenburg district heating network. The project is one of six global projects testing the possibilities of time-based green power. The first results of the pilot project are expected this autumn. The link between Princess Amalia Wind Farm and the electrode boiler in Ypenburg, which together with a number of gas boilers provide heat for the local district heating network, enables testing of the measurements, procedures and software required to provide time-based certification in the future. Production and consumption of green electricity will be measured and certified every hour and quarter of an hour. The current certification system, which uses Guarantees of Origin (GoOs), does not support time-based certification. Using a time indication, a guarantee can be given that green electricity is produced and also consumed within a single hour – or even within a quarter of an hour. This is more in line with an energy system in which the balance between consumption and generation is becoming increasingly important as weather-dependent solar and wind power production increase, Eneco said. A more transparent certification system gives private customers and companies more accurate insight into the sustainability of their electricity consumption. It allows them to make better-informed choices regarding which electricity they want to use, and companies can make their sustainability ambitions even more explicit toward true decarbonization.

FlexiDAO provides its blockchain-based technology to monitor production and consumption on a 24/7 basis, supported by measurement data made available by Eneco. CertiQ is legally responsible for certifying electricity and renewable heat. In this pilot project, CertiQ is investigating how a more transparent, time-based certification system can be integrated into the current sustainable energy certification system.

The project is one of six global projects testing the possibilities of time-based green power which are included in the Report. This is part of EnergyTag: an energy industry initiative in which over 100 companies, governments and NGOs work together to create a more transparent certification system that better reflects the increase in the supply of weather-dependent solar and wind power. The goal is to accelerate the energy transition by offering certifiable green energy 24/7 and foster a transparent, real decarbonization of the electricity grid with the aim of mitigating climate change and dramatically reducing air pollution.

Restart Energy Democracy (RED), Power Ledger and WePower

To create a financially sustainable ecosystem, proof-of-stake approaches are followed to incentivize early adopters to support a platform. For instance, Restart Energy Democracy (RED), an independent EU electricity and gas supply company, launched a decentralized energy supply platform to award green energy certificates to consumers of renewable energy. They allow peer-to-peer direct trading between consumers and suppliers, while reducing transaction costs. RED's go-to-market strategy is based on two franchise tiers, the higher of which demands the ownership of a minimum number of tokens.

A similar system is being developed by Power Ledger. With its own unique trade-matching algorithms, prosumers and consumers can transact available power equitably, without favoring any of the participants. Other characteristics of this platform include pegging of native tokens to a local unit of currency and aggregation of individual meters in a single transaction. The trading group can be configured by either its application host or Power Ledger. WePower also offers an alternative solution on exchanging energy certificates via its native WPR token and auctions. WePower launched a financial derivative product, called Contract for Difference, to mitigate risk in corporate power purchasing agreements (PPAs).

To revolutionize the existing high-cost and cumbersome energy certificates trading, IBM is working on a solution (enerT) to tokenize energy certificates using Hyperledger Fabric and Tokens-SDK. Tokenization of energy certificates in a DLT platform can offer an intelligent solution with regard to full-disclosure certification of energy. In addition to the amount of energy generated by mixed sources, tokens created in the network could also store other useful characteristics such as CO_2 emissions in the energy supply chain. A tokenized energy marketplace would offer a wide range of trusted certificates in terms of energy types and origin. Such a network would allow suppliers and consumers to trade energy certificates efficiently and inexpensively. A tokenized certification unit would be like what the container did for the shipping industry.

The enerT solution is being developed as an energy-friendly solution on a private, and permissioned-based technology to eliminate energy consumption by its network operations. Hyperledger Fabric's energy-efficient consensus protocol is based on RAFT, a leader-follower approach. This factor leads network operations to consuming limited energy, compared to mining algorithms with mathematical puzzles (such as Proof-of-Work), often used in several public networks.

Power Transition

A microgrid management system called Power Transition is a platform developed to change how energy is utilized, managed, and traded by governments, businesses, and individuals. They're heading toward developing a peer-to-peer energy trading and microgrid management system that will begin with granting consumer homes the ability to establish a local grid that can operate independently and create a marketplace between residences during times of excess or power outages. It uses energy storage and power management systems to optimize multiple sources of energy supply and demand for energy trading.

Power Transition chose Hedera based on its decentralized governance, security and stability. It integrated the "Microgrid as a Service" (MaaS) platform, built on the Hedera Hashgraph, to provide instantaneous micropayments while monitoring and managing individual units of energy throughout their lifecycles with accountable pinpoint accuracy. In Hashgraph, in contrast to blockchain, each container of transactions is recorded in the ledger and none is lost, so it is more efficient than blockchains. All branches continue to exist forever, and are woven together into a single whole. All Hedera network connections are encrypted using TLS 1.2, every transaction is digitally signed and the hashgraph is produced with cryptographic hashes. All of the algorithms and key sizes were picked to be CNSA-Suite compliant.

Hedera's Token Service (HTS) allows the ability to issue and configure tokens on the Hedera network offering a more efficient alternative to smart contract token creation. With HTS, users can localize energy trading Dapps for any customer regardless of country or currency of operation. With the latest update to the Digital Energy Platform (DEP), Hedera can enable supply-chain participants to track and trade electricity while balancing the use of power in a decentralized renewable energy grid at low cost and minimal carbon impact. Power Transition has integrated HTS as fiat currency-linked energy tokens utilizing the Hedera Consensus Service (HCS) and mirror nodes.

This has revolutionized how consumers can move electricity and other forms of value across the energy sector. HTS has streamlined operations while lowering risk, increasing the company's capacity to quickly localize its Dapps to international markets.

The Hedera public network native currency is HBAR, which is a low-cost, energy-efficient cryptocurrency. It is used to power decentralized apps and defend the network from bad actors. Tokens created using HTS inherit many of the characteristics of HBAR, such as the asynchronous byzantine fault tolerant (ABFT) consensus, predictable low fees, governance and ability to operate thousands of transactions per second with finality.

There's currently a proof of concept P2P residential microgrid running in the system on 47 newly built homes in Corby, England. Carbon Free Group, which is the major shareholder in Power Transition, is delivering this zero-carbon housing development along with its members. The buildings are equipped with multiple levels of sensing and monitoring devices used to analyze and inform how people are utilizing energy.

Milestones achieved included:

- Optimization of energy production and consumption at individual as well as community levels
- Improving FFR and demand response with National Grid by improving battery charge-discharge cycles
- Accurately monitoring and controlling energy tariffs through tokenization
- Reduction in electricity bills for consumers – £620-770 per year
- Reduction in the emission of greenhouse gasses – 110-130 tonnes of CO_2e per year

VI. Conclusion

The innovation by players focused on the energy transition reflects a new reality that we live in. The focus is now on the ordinary citizen and making impact at the community level as a collective on a cooperative basis. This reflects genuine buy-in from prosumers despite the political and economic system they live in. It also reflects the opportunity to create a new culture around conservation and consumption despite cultural drivers, leveraging the opportunity to build a universal culture and be better prepared for future energy crises. Geographical differences in attitudes exist across different regions and the same actions may reflect different values. For example, in the US, energy security is considered a more critical goal than mitigating climate change. As such, renewable energy is propelled by different drivers in the US from those in Europe. With regard to electric vehicles, different attitudes around transportation (in Europe versus North America) and culture are important for adoption, with lobbying groups holding more power in North America. The millennial attitudes around reducing carbon footprint are ultimately a powerful force driving adoption based on consumer consciousness.

The use cases discussed in this paper have leveraged a trickle-down effect from the policy side and financial incentives that have facilitated energy markets. Our recommendations focus on best practices and what has and has not worked from these use cases to create enabling environments for new market models. They offer tremendous learnings for regulators and financiers.

While the use cases elaborated on in this technical briefing reflect the successful tokenization of energy across a variety of business models, there remains much work to be done to leverage the prosumer as a core stakeholder in the new energy paradigm. Examples of successful supporting initiatives abound, but enabling the token economy in the power market will not happen overnight. Evolving our relationship with energy consumption from conservation efforts to bidirectional transactions will require leaders across technologies, public- and private-sector organizations and investors to drive digital physical convergence that enables Programmable Energy.

Recently, IBM participated with 2Tokens on a roundtable to address the current challenges related to tokenizing energy. Participants arrived at preliminary recommendations around the following:
1. Standardization of the token taxonomy and investment frameworks around smart grids, packaged energy, carbon markets and financing models with 2Tokens to follow up and deliver demonstration projects
2. Coordination across regulators overseeing investment, utilities, energy and tax policies to effectively remove barriers to adoption and
3. Construction of decentralized marketplaces for energy.

Recommendations with a view to leveraging citizen-produced electricity that will limit global warming and lead the way to inclusive climate resilience through the adoption of programmable energy include:

- Work toward barrier-free access to new models of trading transactions in power grids for electricity produced by citizens who are also consumers (prosumers)

- Unearth and enable new business models for participants in a position to aggregate and optimize demand signals

- Align governance, regulation, safety standards and access rules on common grounds and common purpose

- Develop common international frameworks relating to any and all aspects of consumer-generated electricity, with the aim of reducing barriers and democratizing grid access

- Apply tokenization and tokenomics to optimize economic value for the prosumer, taking full advantage of all the possibilities of distributed ledger technology

- Use best practices from known and established use cases to convene the alignment and development of international conventions and norms

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End Notes

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