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IRENA Innovation Landscape Report

The growing role of Blockchain in the power sector

Open Energy Marketplaces and the Enabling Technologies
Brussels, 8 March

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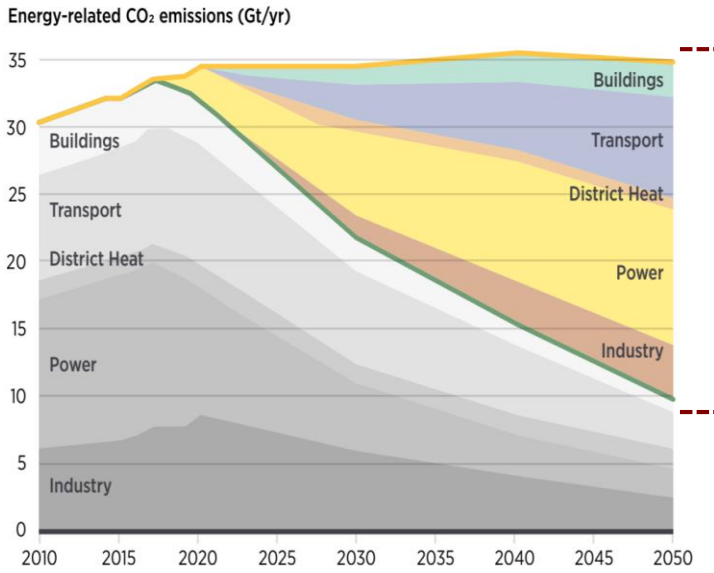
IRENA's Report

"Innovation landscape for a renewable-powered future"

Ongoing Energy Transformation - drivers

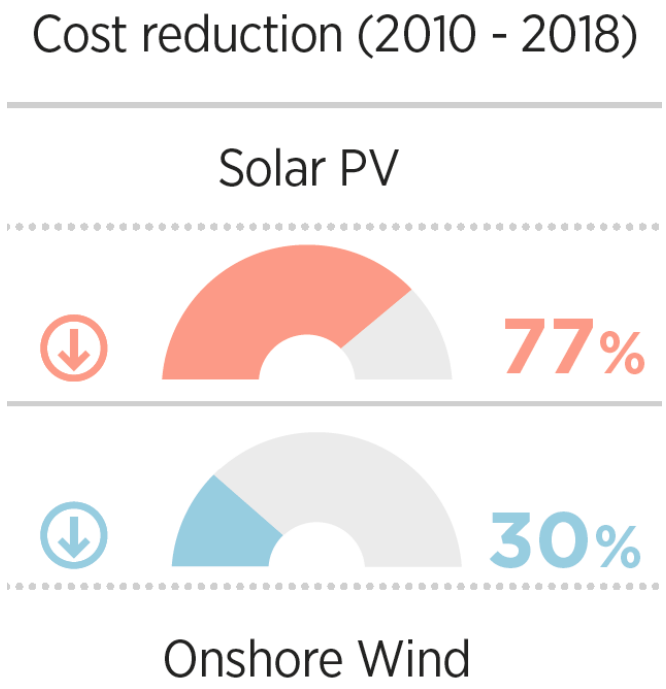
- **Policy imperatives**
  - Sustainable Development and Economic Growth (SDGs)
  - Climate and Environmental agenda (Paris Agreement)

Annual energy-related CO_2 emissions and reductions, 2015-2050 (Gt/yr)



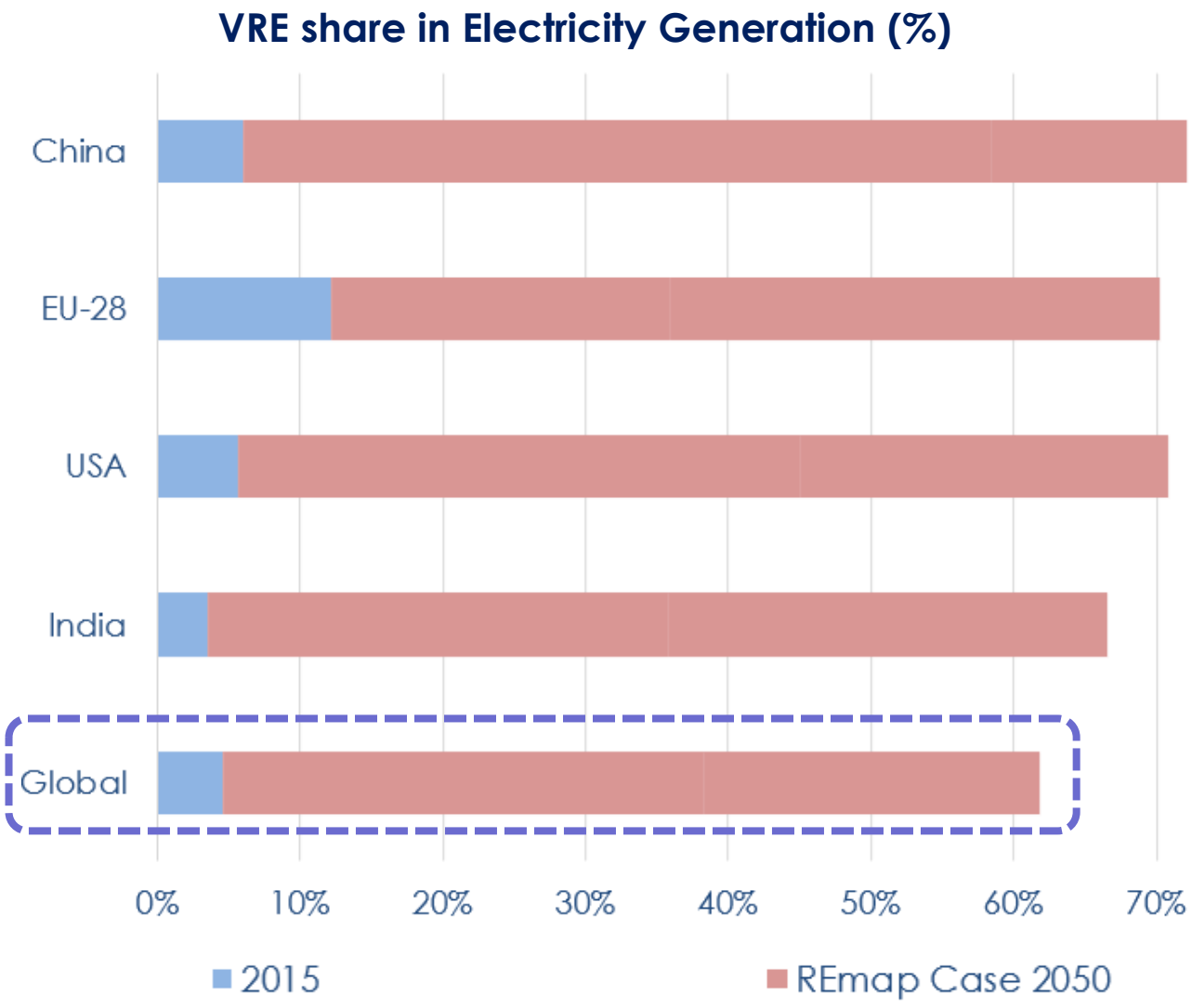
94% of needed emission reductions from RE and EE

- **RE Strong Business case**
  - Policy frameworks, business and technology innovation
  - Dramatic cost reduction



Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Wind and PV at the core of the energy transition



> 60% Global VRE Share by 2050 in Paris Agreement aligned case

- Wind and PV are **variable energy sources** – addressing variability is crucial for high deployment.
- Today's innovation challenge – **integrating high shares of wind and PV at lowest-cost** in power systems.
- **Power-system flexibility** is key to the cost-effective use of renewables.

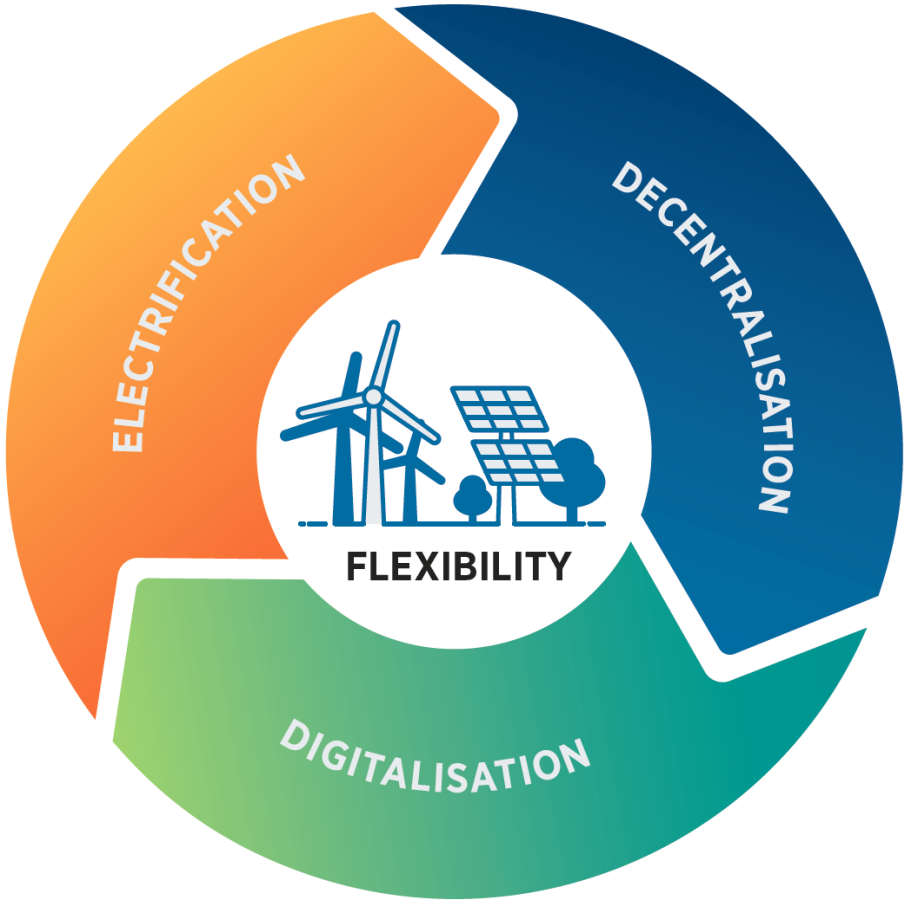
Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Innovative solutions to increase power systems flexibility propelled by three trends

- **Decentralisation –impact on supply side-.** Wind and PV is largely centralized today but distributed generation - notably rooftop PV, ~ 1% of all electricity generation today – is growing bringing new flexibility opportunities at demand side

- **Electrification –impact on demand side-.** It plays in two ways, may decarbonize end-use sectors through renewable electricity and, if done in a smart way, become a flexibility source to integrate more renewables in power systems

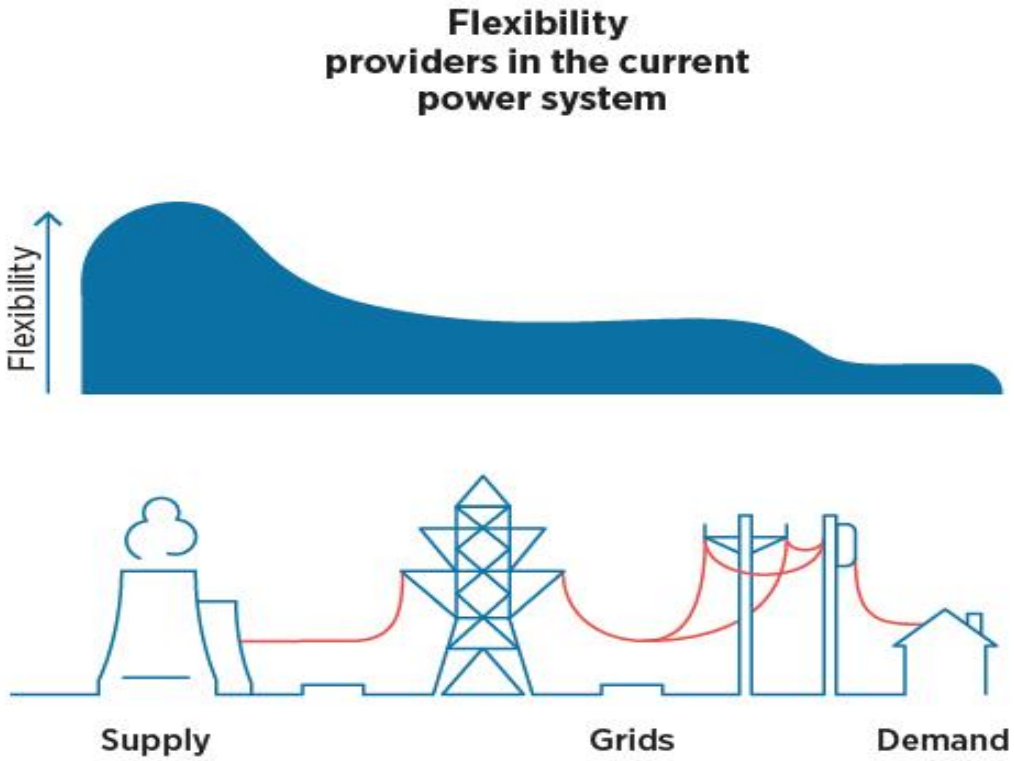
- **Digitalisation –impact on system integration-.** Key enabler to amplify the energy transformation by managing large amounts of data and optimizing systems with many small generation units



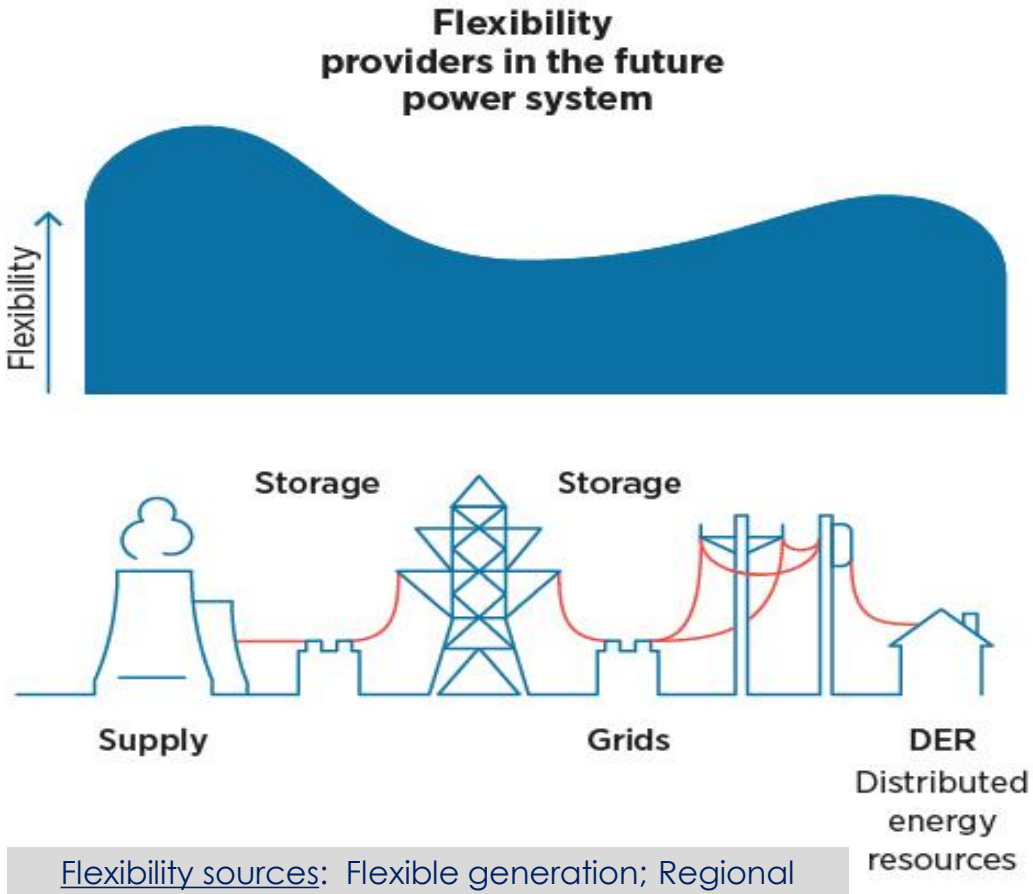
Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Innovation unlocks flexibility across whole power system

Smart RE-electrification supported by Digitalisation representing **62% of global energy CO2 reduction** potential by 2050



Flexibility sources: Flexible generation



Flexibility sources: Flexible generation; Regional interconnections and markets; Demand response; Storage; Power to X

Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Landscape of Innovation for Power Sector – 30 innovations in Four Dimensions

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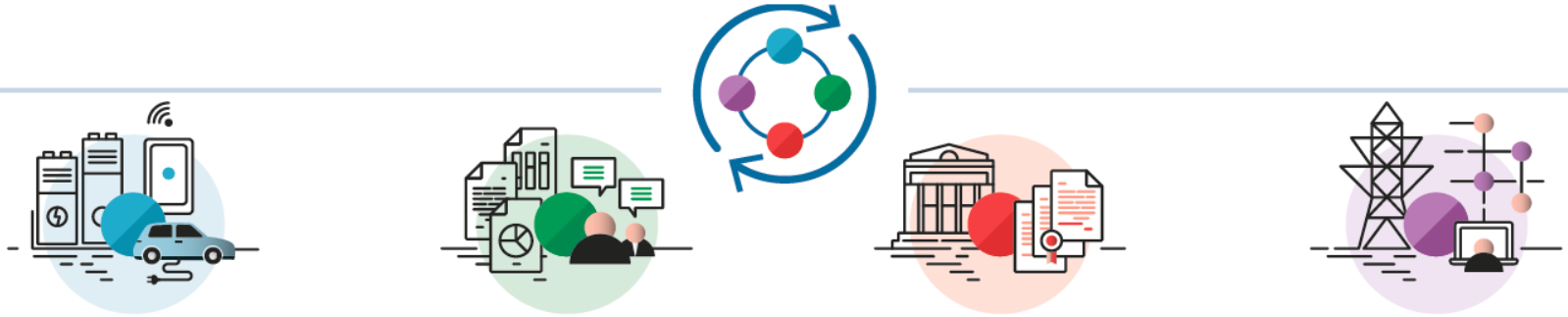

ENABLING TECHNOLOGIES

1	Utility-scale batteries
2	Behind-the-meter batteries
3	Electric-vehicle smart charging
4	Renewable power-to-heat
5	Renewable power-to-hydrogen
6	Internet of things
7	Artificial intelligence and big data
8	Blockchain
9	Renewable mini-grids
10	Supergrids
11	Flexibility in conventional power plants

BUSINESS MODELS

12	Aggregators
13	Peer-to-peer electricity trading
14	Energy-as-a-service
15	Community-ownership models
16	Pay-as-you-go models

MARKET DESIGN

17	Increasing time granularity in electricity markets
18	Increasing space granularity in electricity markets
19	Innovative ancillary services
20	Re-designing capacity markets
21	Regional markets
22	Time-of-use tariffs
23	Market integration of distributed energy resources
24	Net billing schemes

SYSTEM OPERATION

25	Future role of distribution system operators
26	Co-operation between transmission and distribution system operators
27	Advanced forecasting of variable renewable power generation
28	Innovative operation of pumped hydropower storage
29	Virtual power lines
30	Dynamic line rating

Free download of report at:
https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future

Innovations as building blocks of Flexibility
Solutions tailored to country/system context

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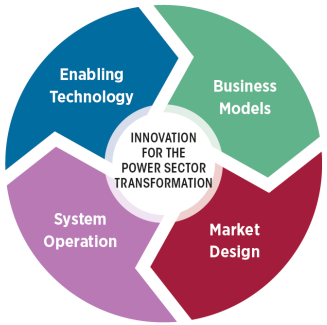
Combine Innovations to Create Flexibility Solutions



Example 1:

DER providing services to the grid

- BtM batteries / Smart Charging for EVs / Power-to-heat + IoT / AI & Big Data / Blockchain
- Aggregators
- DER participation in wholesale market / New products on ancillary service market
- DSO-TSO co-operation

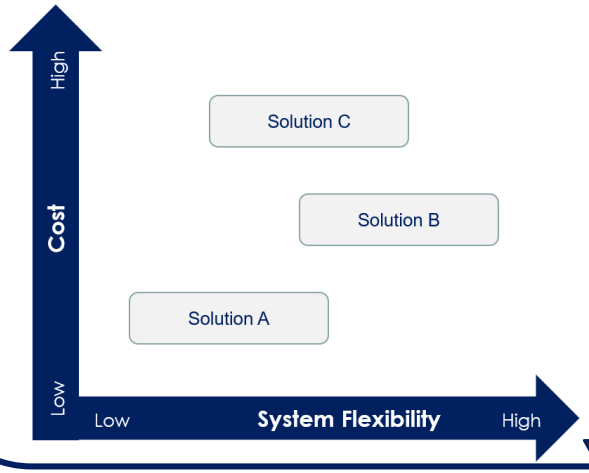
Example 2:

Increase VRE integration while avoiding grid reinforcements investments

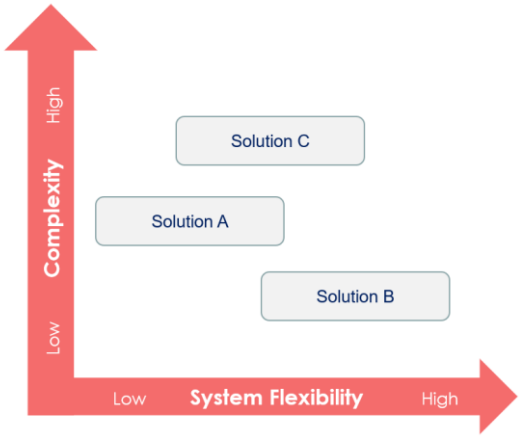
- Utility-scale battery storage / Power-to-hydrogen / Power-to-heat + IoT / AI & Big Data
- Virtual power lines / Dynamic line rating

Assess impact and deployment of solutions

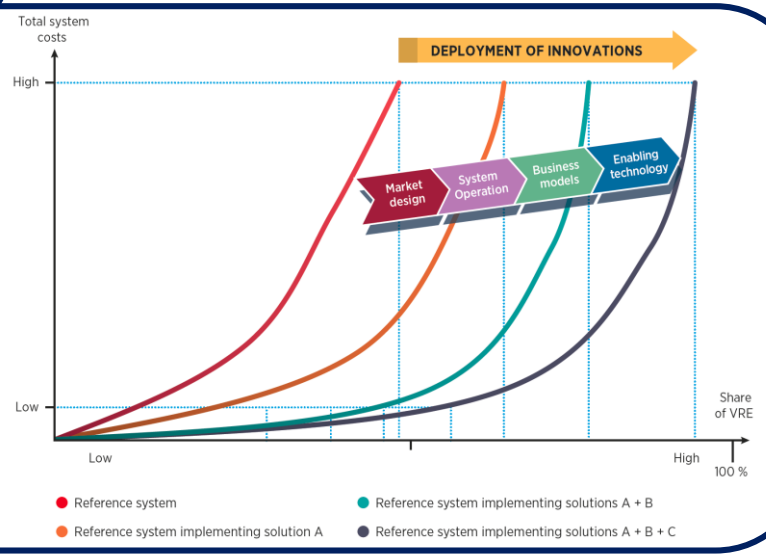
Impact vs. Cost:



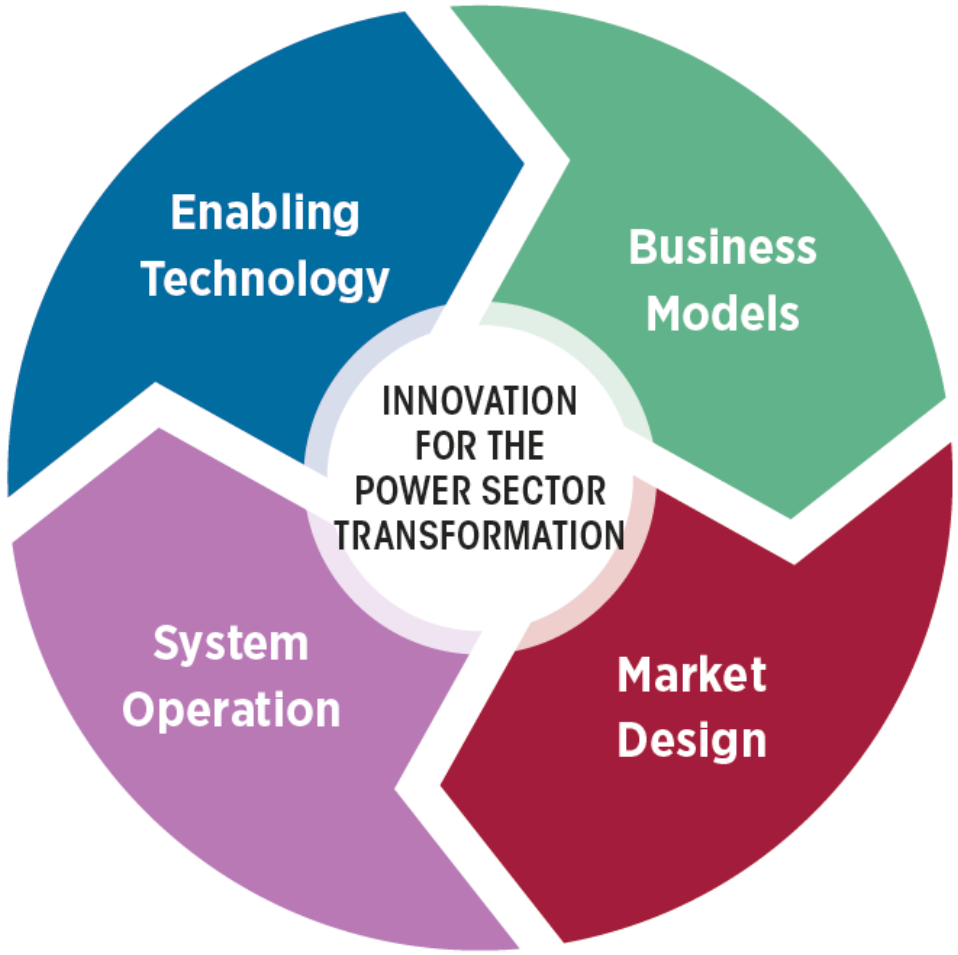
Impact vs. Implementation challenges (e.g. regulatory changes, new role of actors):



Implement cost-effective solutions tailored to each power system



Combine Innovations to Create Flexibility Solutions



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Increase VRE integration while avoiding grid reinforcements investments

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Combining innovations into solutions – 11 solutions

FLEXIBILITY

SOLUTIONS

SUPPLY-SIDE FLEXIBILITY SOLUTIONS

I	Decreasing VRE generation uncertainty with advanced generation forecasting
II	Flexible generation to accommodate variability

GRID FLEXIBILITY SOLUTIONS

III	Interconnections and regional markets as flexibility providers
IV	Matching RE generation and demand over large distances with Supergrids
V	Large-scale storage and new grid operation to defer grid reinforcements investments

DEMAND-SIDE FLEXIBILITY SOLUTIONS

VI	Aggregating distributed energy resources for grid services
VII	Demand-side management
VIII	RE mini-grids providing services to the main grid
IX	Optimising distribution system operation with with distributed energy resources

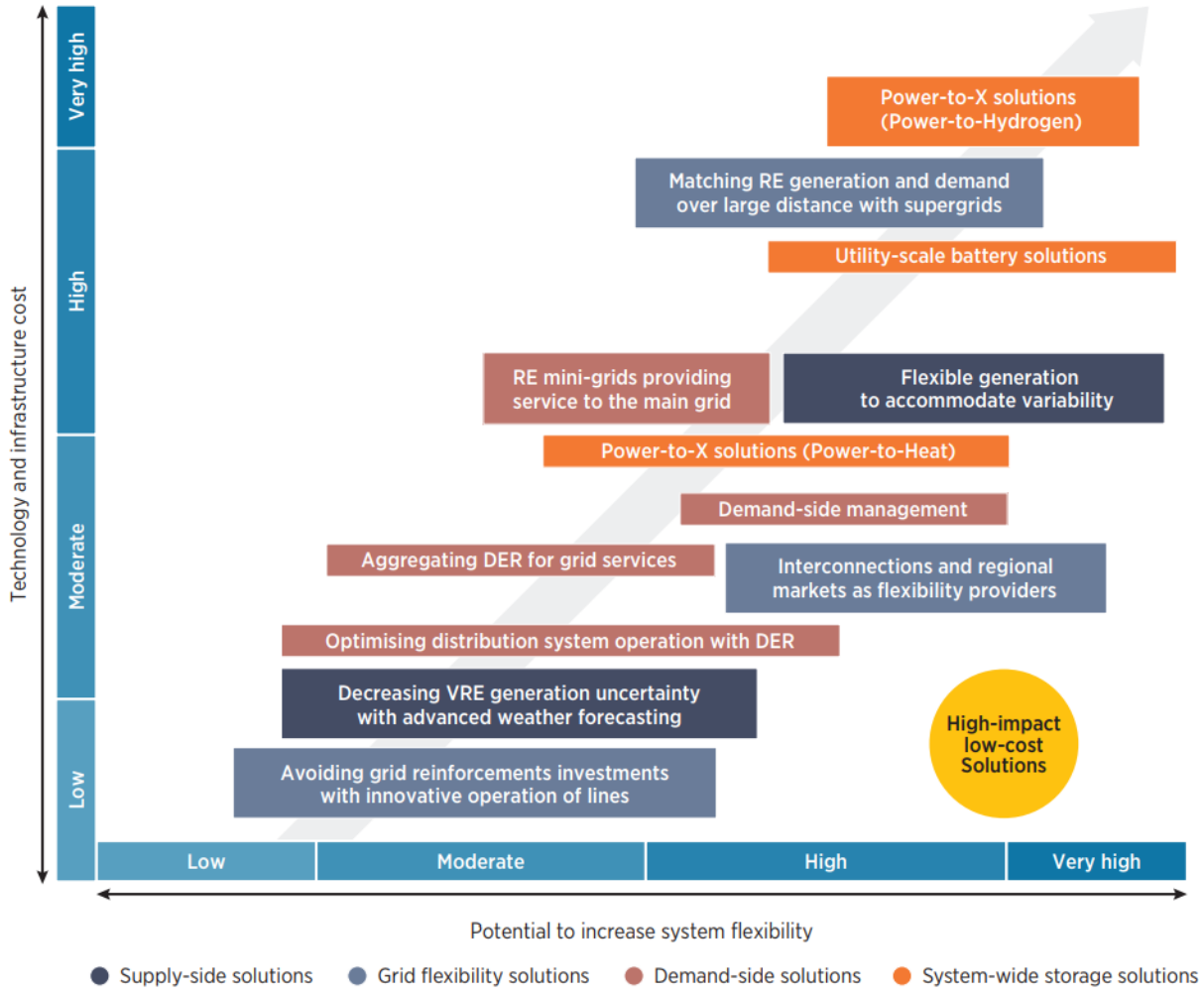
SYSTEM-WIDE STORAGE FLEXIBILITY SOLUTIONS

X	Utility-scale battery solutions
XI	Power-to-X solutions

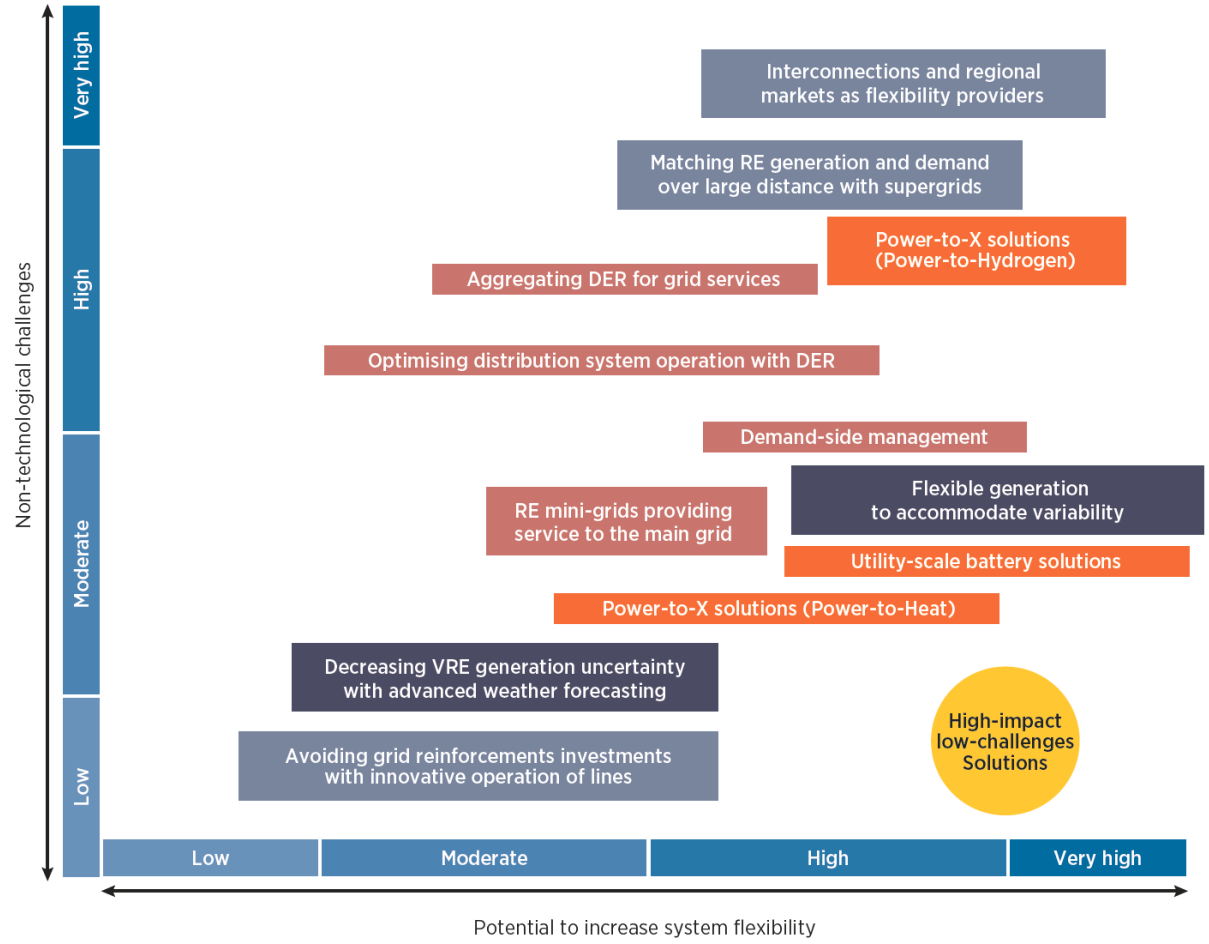
Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Priority solutions based on country/system context

Flexibility vs Cost

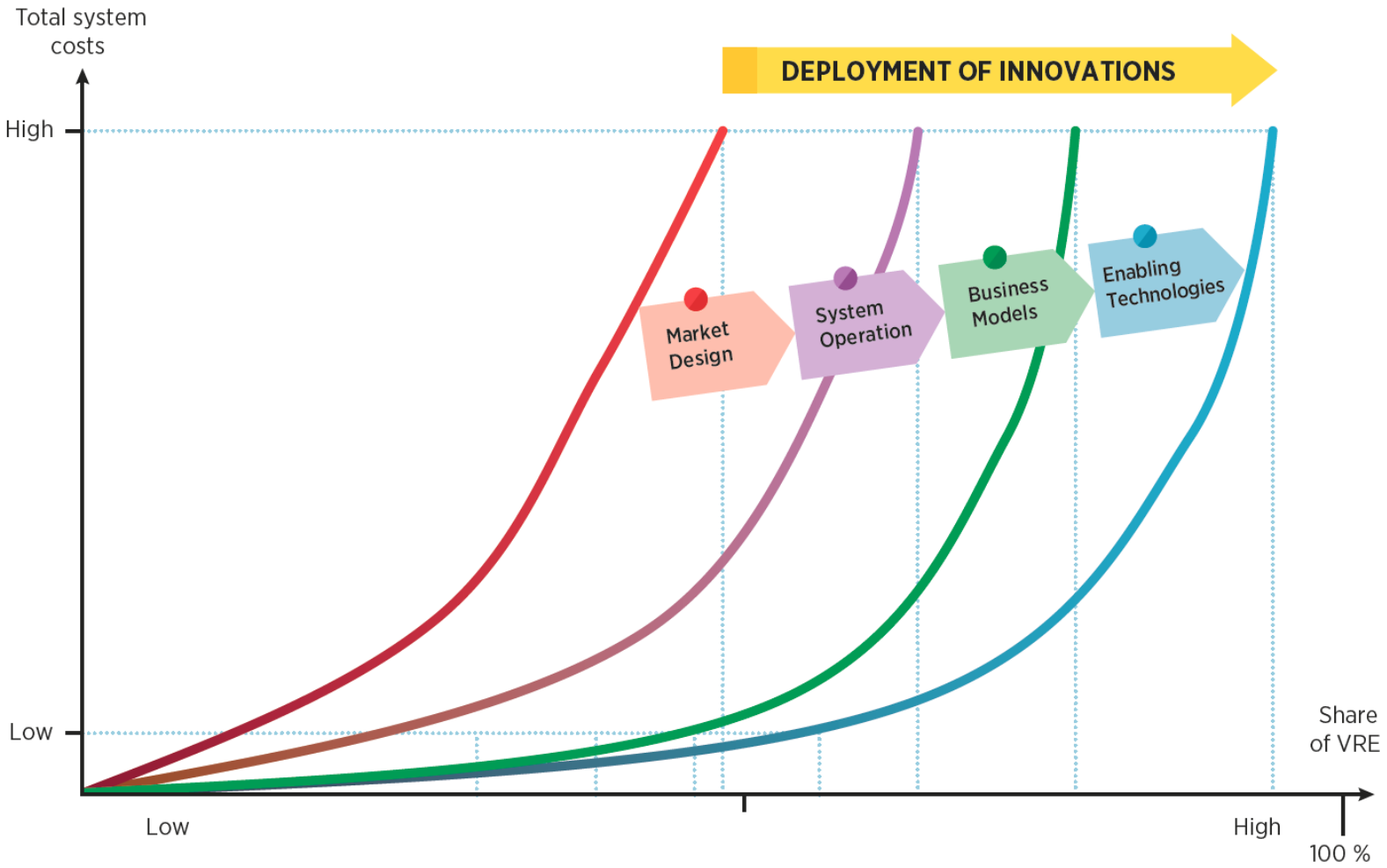


Flexibility vs Implementation Complexity



Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Focus on high-impact & low-cost solutions



The more innovative solutions are implemented, the higher the share of VRE integrated and the lower the system costs

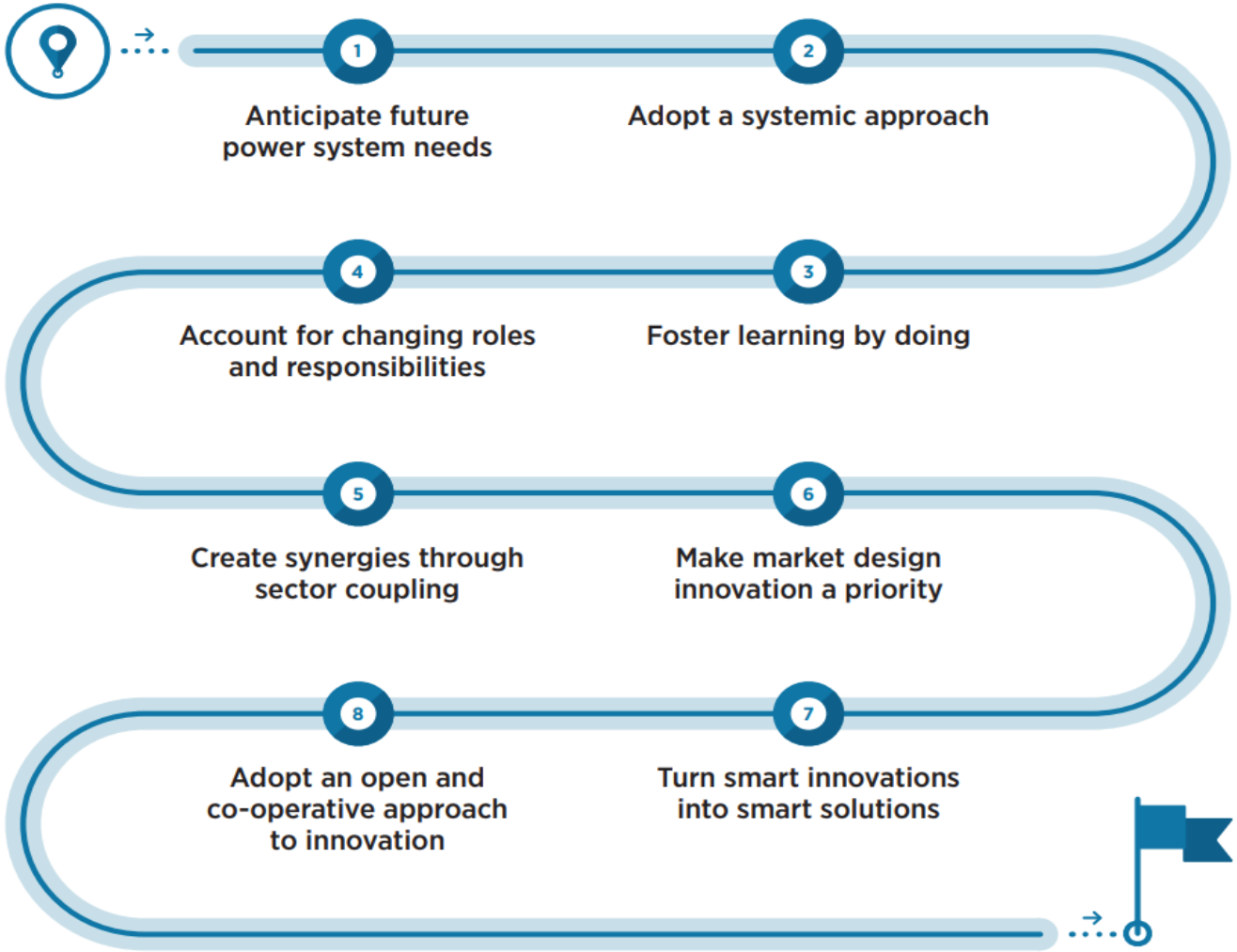
I. **Unlocking existing flexibility** is the first action to be taken: restructuring of market and operations is key.

II. At one point a system-specific **least-cost mix of investments** in T&D, storage, Demand Response as well as digitalisation will be needed to increase flexibility

Toolbox to be applied to your country?: Call us (contact details on the last slide)

Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

Eight-step innovation plan for power sector transformation



Source: IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables

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IRENA's Innovation Brief
"Blockchain"

Blockchain – Innovation Brief and Innovation Week 2018

- Blockchain is a tool that can be used to accelerate the energy transition and is not a goal in itself. Increasing complexity requires newer, smarter tools.
- Blockchain has a strong business case in decentralised systems, not suitable for all applications. When does it make sense to use blockchain (?)
- Blockchain has the potential to create new markets/value based on 'Data Economy' [value from data-based services instead of kWh]
- Challenges remain in asset registration and integration, interoperability and scalability.

https://innovationweek.irena.org/

INNOVATION WEEK 2018

solutions for a renewable-powered future

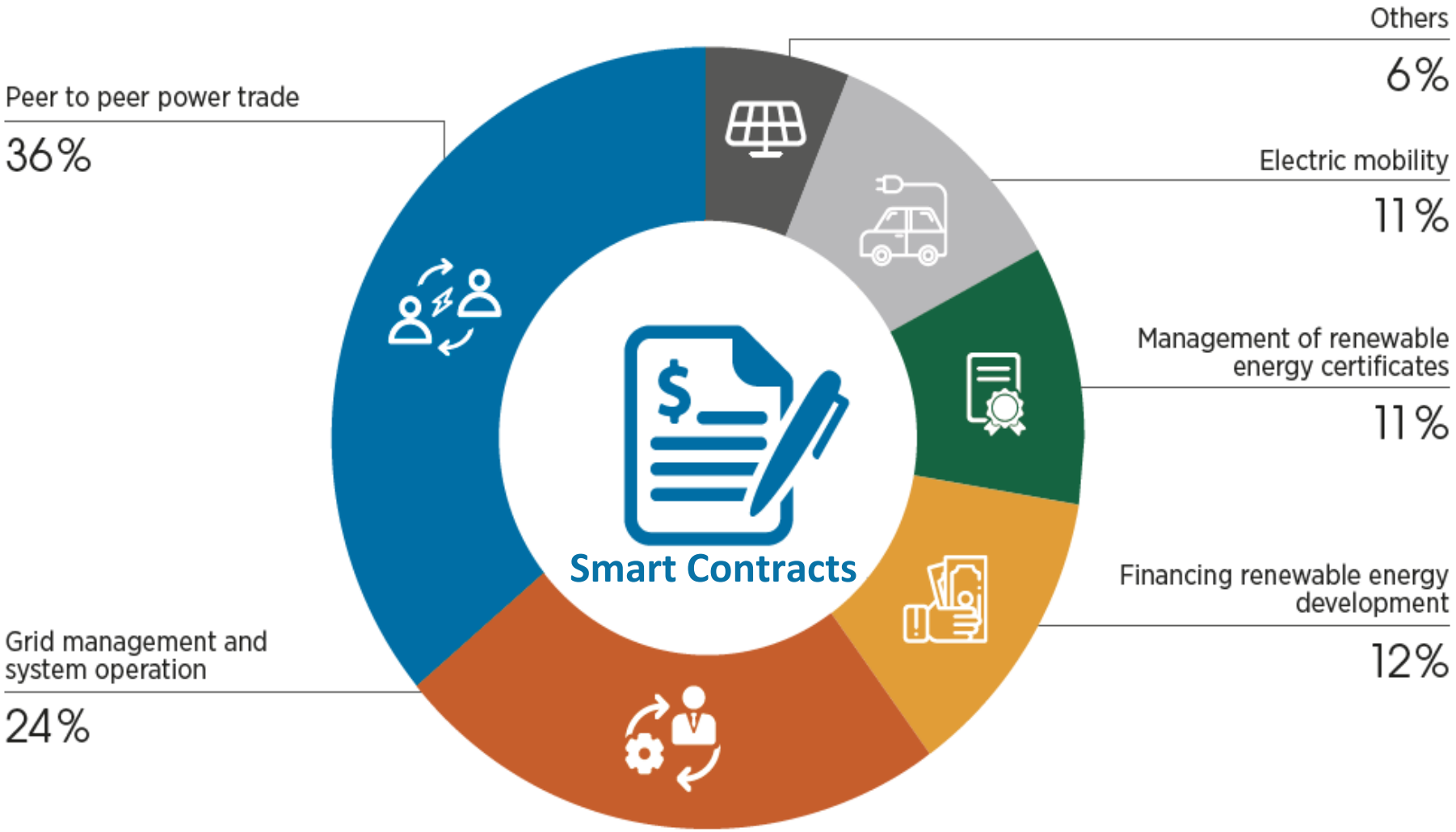
Blockchain Investment (EU vs ROW)

- **1bn invested** in Energy (71 companies), Logistics (34), IoT (24), Mobility (19), and Agriculture & Food (10) between 2017 and mid-2018
- **723m in funding is centered in Europe**
- Blockchain investment in energy sector expected to cross **$5.8 billion by 2025**

As of mid-2018

Source: Cleantech Group

Current uses of blockchain in the power sector



Note: Data as of July 2018.
Based on: Livingston et al. (2018), Applying Blockchain Technology to Electric Power Systems.

When does it make sense to use blockchain or other DLT?

Source: IRENA (2019) Blockchain: Innovation Landscape Brief

Regulations in the EU

Regulation is essential in enabling and steering large-scale blockchain applications

- As set out in its "Digital Single Market" policy strategy, the European Commission aims to develop a common approach to the development of blockchain for the EU

- EU Blockchain Observatory and Forum launched Feb 2018
  - EU Observatory seeks to highlight key blockchain related developments, promote European blockchain-related activity, and improve European engagement with stakeholders that are involved in blockchain-related activities

- April 10, 2018, 22 European countries signed a "Declaration on the establishment of a European Blockchain Partnership.
  - Intended to encourage member states to exchange technical and regulatory experience with blockchain technologies and to prepare for the launch of EU-wide blockchain applications.

- In total, the European Commission has provided €83 million in funding for blockchain-related projects and could commit up to an additional €340 million from 2018 to 2020.

Source: IRENA (2019) Blockchain: Innovation Landscape Brief

Regulations and government buy-in (Singapore, ROK)

Singapore

- Singapore Power Group launched a blockchain-powered marketplace for RECs in October 2018. Claimed as world's first blockchain-powered marketplace in REC
- Onboarding consumers from Nov. 2018, the Open Electricity Market (started by the Energy Market Authority) allows consumers to buy electricity from any provider. Electrify is building a decentralized marketplace for energy using blockchain.
- In Dec 2018, Enterprise Singapore (a government agency set up to develop the startup ecosystem) announced they are supporting a new blockchain accelerator program called Tribe Accelerator.

Republic of Korea

- South Korea's government will spend $3.5 million) to set up a blockchain-enabled virtual power plant (VPP) in the city of Busan (Korea's second-largest city 3.5M).
- In Nov. 2018, KEPCO, Korea's largest power provider announced it will use blockchain and other innovative energy solutions to develop its next-generation micro grid (MG), also for H2 production.
- In June 2018, a South Korean governmental agency — the Industry-SW ICT Convergence Association (WICA) — also revealed plans to establish a blockchain center in Busan modeled on Switzerland's Crypto Valley.

Source: IRENA (2019) Blockchain: Innovation Landscape Brief

Key factors to enable deployment

Demonstration projects and Regulatory sandboxes to better understand:

Improving performance and scalability	Unveil benefits for regulators and other actors	Power consumption	Needed infrastructure and standards	Cybersecurity and data privacy
• Increase number of TPS. From 10 - 30 to 65 000 TPS. Sidechains (interoperability) • From proof of work to proof of stake or authority	• Regulator with access to real-time data of all participants strengthen data analytics • Simplify interaction between regulator and regulated entities (e.g. DSO)	• Bitcoin 300 kWh per transaction, 2018 3.4 GW (proof of work) • Proof of authority or proof of stake (Ethereum is shifting)	• Advanced metering infrastructure • Interoperability based on harmonized standards and protocols	• Blockchain increases data security, but any vulnerable point (?) • Data management, analytics and PRIVACY

Source: IRENA (2019) Blockchain: Innovation Landscape Brief

European Union – open questions on blockchain for a low-carbon electricity sector

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?

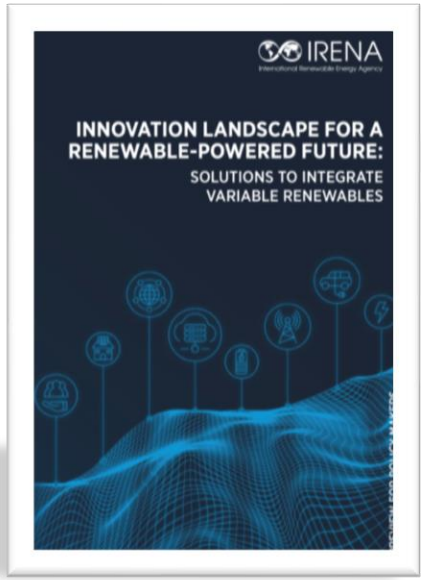
Questions to experts (you)

GOVERNANCE: How to coordinate all actors involved (ICT, retailers, DSO/TSO, regulator, consumer), who has authority, how to ensure transparency and compliance with other related electricity regulations. Should we look and learn from other sectors beyond energy

Data privacy: comply with GDPR (EU) but foster sharing data (?). No data sharing, no open energy market

Interoperability: what is needed in terms of standards

Thank you



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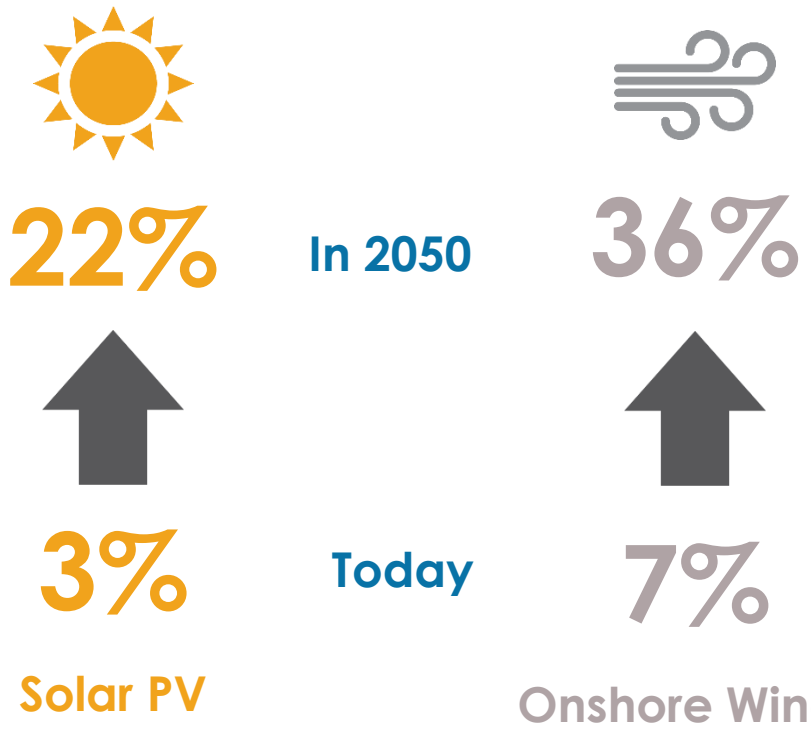
Backup slides

Wind and PV at the core of the energy transition

Onshore Wind and Solar PV electricity shares in the generation mix



- Wind and PV are **variable energy sources** – addressing variability is crucial for high deployment.
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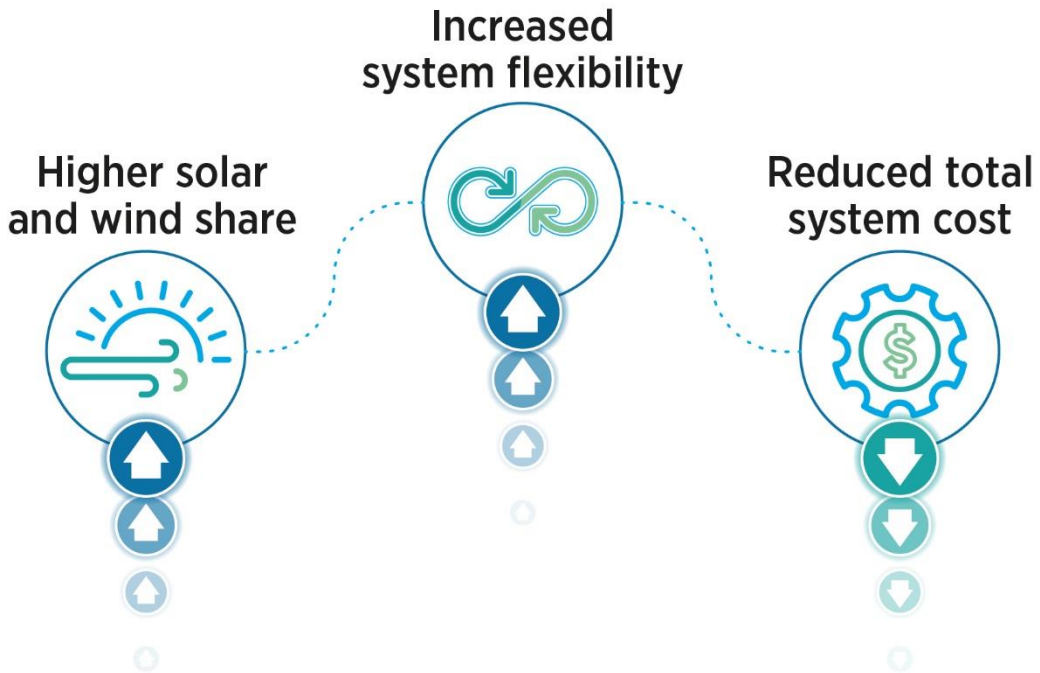


Source: IRENA (2018), Global Energy Transformation: A roadmap to 2050

Digitalisation

Digitalisation can enable smarter, better-connected, more reliable and ultimately lower-cost energy systems

- Digital innovations (such as Artificial Intelligence, the Internet of Things, Blockchain, etc.) are starting to significantly impact power systems in many different ways, with applications in supply, system operation and demand being piloted by both start-ups and established energy companies…

Challenges

- …but, that disruptive potential is only beginning to be understood and is far from being fully exploited. The implications for established models and actors and the risks are not yet fully understood.

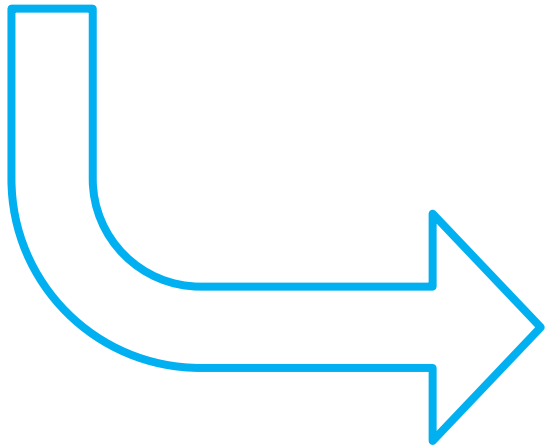
Implications

- Technologies exist, but smart applications are still limited. Energy systems should make far more use of the “smartness” that digital innovations enable.
- Many more pilots and deployments of digital-enabled solutions are needed in a wider range of circumstances.

Innovation team blockchain work

Digitalisation work:

- Internet of Things
- Artificial Intelligence
- The role of the new consumer
- **Blockchain**



1. **Innovation Landscape Report**
   a. Blockchain brief
2. **Innovation week 2018**
   a. Blockchain session

Blockchain technology - Potential benefits

➜ Reduced transaction costs

➜ Increased transparency

➜ Increased security via cryptography

➜ Increased automation via smart contracts

➜ Increased participation by new/more actors via decentralisation

Extent of blockchain activity in the power sector

Description	Value
Number of companies working in blockchain in the power sector	189
Number of companies leading blockchain projects in Grid Edge space	**32**
Amount invested in blockchain power companies	USD 466 million, 79 % of which came from Initial Coin Offerings
Amount raised by start-up companies in 2017 to apply blockchain technology to power sector	**USD 300 million**
Number of projects happening globally	71 announced

Note: Data valid as of 31 July 2018.
Source: Metelitsa (2018), "A snapshot into blockchain deployments and investments in the power sector".

What to expect in 2019

- More industry players than ever will enter the market
- Blockchain attracts a new wave of energy sector investment
- Major, large-scale pilots bring blockchain closer to true commercial deployment
  - Belgian TSO Elia using blockchain for demand response, EWF Affiliate and Netherlands grid operator Stedin's unique layered energy system model for community-based energy trading, and the aforementioned Iberdrola-FlexiDAO collaboration on renewable energy solutions)
- Using blockchain technology to facilitate EV charging events will receive major focus and attention
- M&A heats up as the nascent market starts to mature
  - Pretenders will disappear while utilities and grid operators adopt viable, mature solutions

Innovation Landscape Report – solutions to integrate variable power sources

The report *Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables* elaborates on:

- 30 Key innovations to transform the power sector across four dimensions: enabling technologies, business models, market design and systems operation.
- >200 real-world examples of projects trialling and implementing those innovations
- 11 flexibility solutions created by combining the 30 innovations
- Impact assessment of the flexibility solutions based on their cost and their complexity to implement
- An eight-steps innovation plan for the power sector transformation

Innovation Week 2018 – key takeaway

Increased power sector complexity requires greater intelligence, transparency and automation. **Blockchain can help.**

INNOVATION WEEK 2018

solutions for a renewable-powered future

Examples

- **The Energy Web Foundation** (EWF) is developing the Energy Web Chain—an open-source blockchain platform specifically designed for the energy sector's regulatory, operational, and market needs. EWF's growing network of more than 90 Affiliates are actively building and testing dozens of applications.

- **Electron** is establishing new forms of collaboration through the creation of marketplaces that can stack multiple bids across the electricity system.

- **The Sun Exchange** is opening up new avenues to finance the 1 kW-5MW solar market in emerging economies, which had been previously difficult to finance.

*As of September 2018, GTM Research/Wood Mackenzie Power & Renewables

What is Blockchain?

- ➜ Blockchain is a specific type of distributed ledger technology (DLT), which utilises a chain of blocks as the underlying data structure.
- ➜ Through decentralisation, blockchains can be used to securely record all transactions taking place on a given network without a central intermediary.
- ➜ Blockchain platforms are the base layer on which decentralised applications can be built.
- ➜ Cryptography ensures security and data integrity, while privacy remains intact

Overview - Digitalisation & Decentralisation

- Digitalisation is an enabler for the power-sector transformation, managing data, optimising systems and unlocking flexibility to integrate emerging sources of distributed generation.

- Digitalisation plays a role in large-systems optimisation but it is particularly important in light of distributed energy resources. It facilitates their physical integration while enabling new forms of operation that were not possible previously.

- Digitalisation strengthens the links between all actors in the system, generators, system operators, retailers and consumers and is becoming a necessity in order to maintain visibility of network assets and manage increasingly complex grids.

- Interconnectedness is leading to cybersecurity risks. Digitalisation and decentralisation are helping to make systems more secure as they become more intelligent.

Blockchain Initiatives in the Electric Power Sector, by Category of Application

P2P transactions

The most intuitive—and popular—application of blockchain to the electric power sector is to turn the electricity grid into a peer-to-peer network for customers to trade electricity with one another, for example, by buying and selling excess rooftop solar power.

Yet a truly decentralized, peer-to-peer trading network that upends the existing centralized grid is unlikely to materialize in industrialised countries in the next decade, notwithstanding the ambitions of several blockchain start-ups.

In fact, many of these ventures rely heavily on today's grid. They might market themselves as peer-to-peer networks, but rather than enabling neighbors to actually trade power with one another, these ventures continue to use the existing distribution grid and merely conduct virtual transactions that do not change the physical flow of electricity.

Still, even if blockchain does not replace the grid, it could enable more participants to trade electricity.

For example, Vattenfall, the largest Nordic utility, is running trials in which it uses a private blockchain network to record electricity transactions in which department stores or even individual homes can sell electricity generated by distributed batteries or solar panels; previously, such transactions would have been prohibitively expensive and time-consuming to process.

Blockchain Initiatives in the Electric Power Sector, by Category of Application

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Grid transactions

A range of other electricity trading applications that are less radical than a truly decentralized peer-to-peer network are more likely to gain commercial traction—and support from incumbent utilities and regulatory authorities. These "grid transactions" relate to electricity trading in the context of an electric power system in which the power grid remains integral, even if its form and function changes substantially.

For example, Enel, a large European utility, is spearheading the Enerchain project to use blockchain to enhance existing wholesale electricity markets. In such markets, owners of large power plants sell bulk quantities of power to utilities and retailers that then sell the power to end users.

Currently, these markets require a centralized entity running proprietary software to mediate each electricity transaction, which is both time-consuming and expensive. If these markets listed and cleared transactions on a blockchain network, however, transactions could be validated quickly and cheaply. In addition, the transaction data would be transparent for all market participants to access, enabling more efficient trading.

Blockchain Initiatives in the Electric Power Sector, by Category of Application

Project financing

After electricity trading, the use of blockchain and cryptocurrencies to raise funds for energy projects comprises the second largest category of initiatives to apply blockchain to the electric power sector. This category does not include start-ups that made an ICO to raise funds to then develop, say, a peer-to-peer trading plat-form. Rather, this category comprises ventures focused primarily on using cryptocurrencies to raise funds for energy projects (which tend, overwhelmingly, to be clean energy projects).

For example, WePower is a start-up conducting a demonstration project in Estonia to raise funds for renewable energy projects through cryptocurrency sales. To raise the majority of funds for a wind farm or solar park, WePower will seek traditional debt and equity financing just as any project developer would. But a minority of the project's funding would come from the sale of WePower's new cryptocurrency token, enabling anybody to participate in financing a new renewable energy project. The sale of the tokens would be recorded on WePower's blockchain ledger, and then token owners would be entitled to trade their tokens—over the blockchain network—for discounted elec-tricity generated by the project once it is in operation.

In this way, blockchain networks could make it easier for renewable energy projects to raise funds. They may broaden the pool of potential investors in renewable energy projects by enabling a multi-tude of smaller investors to supply capital.

Blockchain Initiatives in the Electric Power Sector, by Category of Application

Green attribution

One of the most immediate applications of blockchain to electric power is its use to record and trade attributes of sustainability. Examples of such attributes include whether a unit of electricity is renewable and how much emissions resulted from its production.

Currently, systems to track such attributes are centrally managed, complicated, and prone to fraud or errors. Moreover, the compartmentalization of platforms prevents seamless trading of attributes across regions. A decentralized blockchain network could enable transparent, accurate, and frictionless tracking and trading of these attributes, which would accelerate clean energy deployment and carbon emissions reduction.

For example, the Energy Web Foundation's Origin application uses a blockchain to track electricity generation down to the kilowatt-hour and to record attributes such as the carbon emissions associated with power production. Doing so could enable more accurate calculation of carbon offset credits, which offer a mechanism to trade credits for carbon emissions reduced to balance out emissions created elsewhere, for owners and consumers of low-carbon electricity.

Recognizing this potential, several utilities and firms, including Engie, Microsoft, and Singapore Power, are participating in pilot projects that use Origin

Blockchain Initiatives in the Electric Power Sector, by Category of Application

Electric vehicles

The line between the electric power and transportation sectors is blurring as a result of the rising popularity of EVs. Such vehicles, however, still face substantial barriers to customer adoption—in particular, a scarcity of public charging infrastructure can dissuade potential buyers. Blockchain networks that enable private owners of charging infrastructure to seamlessly sell charging services to EV owners could improve the appeal and uptake of EVs.

For example, the Californian start-up eMotorWerks and the German utility-backed start-up MotionWerk have partnered on a pilot project in California to create a marketplace for EV charging. The initiative would enable households that own chargers to rent those to EVs, in a fashion similar to how a homeowner might rent a room to a guest via Airbnb. The start-ups reckon that a blockchain network can facilitate a large number of small transactions of fractional units of electricity and do so swiftly, securely, and transparently.

Blockchain Initiatives in the Electric Power Sector, by Category of Application

Other applications

Most of the initiatives that fall outside the aforementioned categories have aimed to use blockchain to manage a large collection of assets. For example, the Finnish start-up Fortum aims to help electricity customers manage a range of internet-connected appliances. By managing and recording the energy use of appliances, such as heaters, in response to price signals from the grid, it aims to save customers money. (Still, for customers to actually harness their appliances in service of the grid's needs will require the creation of a distribution market and a system operator that sets granular prices.)

Some utilities are also seeking to use blockchain networks to better manage their assets. For ex-ample, the start-up Filament is working with an Australian utility in the Outback to install sensors and record data about the weather and the health of grid infrastructure on a blockchain network, enabling the utility to improve its maintenance efforts. And in the United Kingdom, the electricity regulator Office of Gas and Electricity Markets (OFGEM) is seeking to register customers' electricity meters as digital entities on a blockchain network. The goal is to enable customers to rapidly switch retail electricity providers—currently the switching process takes up to three weeks—by enabling swift and seamless transactions between customers and the retailers of their choice.

Finally, some initiatives have sought to apply blockchain technology to enhance the cybersecurity of electric power systems. For example, a joint initiative of Siemens and U.S. government entities including the Departments of Energy and Defense is conducting a pilot demonstration of using the cryptographic algorithms that underpin blockchain to secure critical power sector infrastructure and prevent unauthorized breaches.