Alianza Energética
Energiepartnerschaft
MÉXICO - DEUTSCHLAND

Blockchain in the Mexican Energy Sector

Fostering digital transformation

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Imprint

Commissioned and published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Offices registered in:
Bonn y Eschborn, Germany

Project
Support for Bilateral Energy Partnerships in Developing Countries and Emerging Economie

Contact
Alianza Energética entre México y Alemania
Av. Insurgentes Sur No. 688, Piso 6, Oficina 602
Colonia del Valle, 03100 Benito Juárez
CDMX, México
+52 55 5536 0330 Ext. 106
www.energypartnership.mx

Francisco Alejandro Contreras del Valle
francisco.contreras@giz.de

Date
October 2020

Digital Version

Designed by
Sk3 Estudio Creativo, CDMX
www.sk3.mx

Photographs
Shutterstock p4. 1474986674 / p5. 1090199027 / p6. 60505837 / p8. 741286714 / p12. 1464963041 / p17. 1006139380 / p19. 635182691 / p29. 686728954 / p31. PF. close-up-process-new-printing-technology / P33. FP business-administrator-action / p34. 1382663033 / p39. 1382663069 / p40. 773006551 / p49. 1171380154 / p51. 588093767 / p52. 143111598 / p53. 602578049 / p54. 741657730 / p55. 677922763 / p56. 1087535381 / p58. 100401259 / p59. 462658072 / p62. 373393660 / p77. FP businessman-using-digital-network / p78. 528985435 / P84. FP 3d-illustration-digital-block-chain / p91. 1060540226 / p93. 1115925887 / p96. FP warehouseman-with-protective / P97. golden-bitcoin-computer-chip / p98-p99 1029377662 / p100. 1375623947 / p103. 382980877 / p105. 618418115 / p106. 776502385 / p108. 272907596 / p111. 691949200 / p112. 1038891523

Acknowledgments

The German-Mexican Energy Partnership appreciates the participation and enthusiasm of all the experts consulted for the preparation of this study.

Special Acknowledgements:

Juan Roberto Lozano, *Head of International and Government Affairs at CENACE*
Luis Guillermo Pineda, *Commissioner of the CRE*
José Aparicio, *President & CEO Siemens Energy Mexico, Central America and the Caribbean*
Rubén Cruz, *Head of Energy at KPMG Mexico*
Hansel Moska, *Modeling, Valuation & Analytics Partner at KPMG México*
Oscar Silva, *Strategy Lead Partner at KPMG México*

Energy Sector acknowledgements:

Angélica Quiñones, *Acting President of the National Solar Energy Association (ANES)*
David Ricardo Sol, *Data and Industrial Automation at BASF*
Francis Pérez, *Founder & CEO of Radamasa Desarrollo Sostenible*
Javier Salas, *Project Developer at Energía Aljaval*
Karla Cedano, *Head of Technology Management at Instituto de Energías Renovables - Universidad Nacional Autónoma de México (UNAM)*
Nicolò Rossetto, *Energy & Climate Researcher at Florence School of Regulation (FSR)*
Pablo Anzorena, *Finance Committee Coordinator at AMEXHI*

Digitalization sector acknowledgements:

Arturo Duhart, *CEO & Founder at Sunwise*
Ben Hertz-Shargel, *Head of Data Science and Demand Management at Rhythm Energy*
Douglas Miller, *Market Development Manager at Energy Web Foundation*
Elizabeth Massey, *Head of Research at the International Energy Research Centre (IERC)*
Emma Díaz Ruiz, *Global Sales & Digitalization Strategy Specialist at Siemens Energy*
Gerónimo Martinez, *CEO & Co-Founder at S2G Energy*
José Miguel Bejerano, *Business Development Specialist at Siemens Energy*
Kira Potowski, *Head of Department of Trade & Investment / Energy Efficiency & Renewables Consultant at the Mexican-German Chamber of Commerce and Industry (CAMEXA)*
Meerim Ruslanova, *Regulatory Analyst at Energy Web Foundation*
Moisés Rosado, *Blockchain & Energy Consultant*
Sean Ratka, *Associate Program Officer at the International Renewable Energy Agency (IRENA)*

Blockchain sector acknowledgements:

Christine To, *Director & Partnerships at Stellar Development Foundation*
Dietrich Korb, *CEO & Co-Founder at Ignus Energy*
Eduardo Rodríguez, *Presdient of FlatStone Capital Advisors Inc. and Advisor to Lumit*
Fernando Vera, *CEO & Co-Founder at Lumit*
Michael Lebbon, *Co-Founder of Emmi*
Nayam Hashiro, *Director of Corda Blockchain Partnerships for Latam at R3*
Nikolaj Martyniuk, *CEO & Co-Founder at WePower Network*
Ole Langniss, *CEO & Co-Owner at OLI Systems GmbH*
Richard Plum, *President of the German Energy-Blockchain Association and Senior Financial Analyst at Procom*
Wilfried Pimenta, *Business development Director & Head of Energy at IOTA Foundation*

KPMG Team acknowledgements:

José Manuel Lasso, *Energy and Strategy Specialist at KPMG México (Energy)*
José Luis González, *Blockchain and Cryptoactive Leader at KPMG México (Blockchain)*
José Nahúm Cortés, *Strategy Director at KPMG México (Digitization)*

Content

Acronyms

AI:	Artificial Intelligence
Address:	Sequence of numbers and letter used to send and receive information on the Blockchain
AML:	Anti-Money Laundering
AMLO:	Andres Manuel López Obrador (Mexico's current president)
ANES:	Solar Energy National Association
API:	Application Programming Interface
Blockchain:	Blockchain: is a distributed ledger, enabling new trust mechanism for information registry
BTC:	Bitcoin
B2B:	Business to Business
B2C:	Business to consumer
CBDC´s:	Central Bank Digital Currencies
CENACE:	National Center for Energy Control
CENAGAS:	National Center for Natural Gas Control
CEL´s:	Clean Energy Certificates
CFE:	Federal Electricity Commission
CFT:	Combating the Financial Terrorism
CH_4:	Methane
CRE:	Energy Regulatory Commission
CONACYT:	National Council for Science and Technology
CONUEE:	National Commission for the Efficient Use of Energy
COP21:	United Nations Climate Change Conference
CO_2:	Carbon Dioxide
CRE:	Energy Regulatory Commission
DApps:	Decentralized Apps
DAO´s:	Decentralized autonomous organization
DAICO:	Decentralized Autonomous Initial Coin Offering
DER:	Distributed Energy Resources
DFT:	Financial Transmission Rights
DLT:	Distributed Ledger Technology, Distributed store of data on a share ledger
DOF:	Official Journal of the Federation
D&A:	Data and Analytics
ERC:	Charge responsible entities
ETH:	Ether
EVs:	Electric vehicles
Gwh:	Gigawatt hour
Hash:	Predetermined code obtained through cryptographic techniques.
ICO:	Initial Coin Offering
IEA:	International Energy Agency
IEO´s:	Initial Exchange Offerings
IoT:	Internet of Things
IPO´s:	Initial Public Offerings
IRENA:	International Renewable Energy Agency
Km:	Kilometer
KPIS:	Key performance indicators
Medium Company	Company with sales of up to 6,500 million MXN and up to 250 employees.
MEM:	Wholesale Electricity Market
MIEM:	Ministry of Energy, Mining and Industry of Uruguay
Mining:	The action of validating and authorizing transactions or new blocks.
Mw:	Megawatt
Mwh:	Megawatt hour
MXN:	Mexican pesos
M2M:	Machine to Machine
NGO:	Non-governmental organizations
Nodes:	Participants that have access to a copy of the ledger
OCDE:	Organization for Economic Co-operation and Development
ONU:	United Nations
O&M:	Operations and maintenance
PEMEX:	Mexican Petroleum Company
PETE:	Special Program of the Energy Transition
PML:	Local Marginal Price
PoC:	Proof of Concept
PPA:	Power Purchase Agreements
Ppm:	Parts per million
PRODESEN:	Program for the Development of the National Electricity System
PRONASE:	National Program for the Sustainable Use of Energy
PoW:	Proof of Work
PV:	Photovoltaic
P2P:	Peer to peer
RPA:	Robotic process automation
SDG:	Sustainable Development Goals
SEN:	National Electricity System
SENER:	Secretariat of Energy
SISTRANGAS:	National Integrated Natural Gas Transportation and Storage System
STO:	Security Token Offering
Twh:	Terawatt hours
UNFCCC:	United Nations Framework Convention on Climate Change
UTE:	National Administration of Power Plants and Electric Transmissions of Uruguay
USD:	US Dollars
Wallet:	Used to store and transfer digital assets
3Ds:	Decarbonization, Decentralization and Digitalization

Executive Summary

The main objective of this report is to provide information regarding the role of digitalization in the Energy Transition, particularly focused on Blockchain technology. The text is aimed towards readers interested in the adoption of digital technologies in the Mexican Energy Sector. Therefore, it includes an overview of both the Mexican Energy Sector and Blockchain technology, seeking to grant relevant stakeholders from both fields with the necessary tools for them to evaluate potential Blockchain applications in the industry. This approach is essential for energy experts to understand the technology at an executive level, while permitting Blockchain specialists that are not familiar with the local market to identify areas of opportunity to design, test and implement solutions.

Additionally, an in-depth analysis of Blockchain adoption within the Energy Sector will include key insights as to when the technology becomes relevant for the industry. Key aspects covered in this regard are: main actors from the Energy Sector and the Blockchain ecosystem (along with their potential roles); challenges the industry is currently facing and how Blockchain could serve as a tool to overcome them; complementary technologies that can add further value to Blockchain by creating synergies; emerging Blockchain business models and existing applications for the Energy Sector; a selection of identified use cases applicable to the Mexican market; main impacts and changes that come along with a technological adoption of this nature; and finally, the main risks to consider when defining a Blockchain strategy accompanied by mitigation strategies to address them. Below are the key findings included in the report:

Key findings

- The Energy Sector is currently undergoing significant changes driven by three key trends in the industry: decarbonization, decentralization and digitalization, also known as the 3D's. This has resulted in high impacts across the entire energy value chain and in the way the industry works.
- Digitalization is a process in which digital technologies are implemented throughout the energy system to accelerate the Energy Transition and help industry leaders overcome challenges the sector is currently facing.
- Disruption in the energy industry does not lay behind the adoption of digital technologies. It is the Energy Transition and the increasing complexity of the system what is disrupting the sector, technologies only act as enablers to accelerate and facilitate this process.
- Organizations in the Energy Sector are exploring and testing applications that leverage several digital technologies to continue driving innovation and overcome industry challenges, with cases that stand out in Blockchain, IoT, AI, Big Data, Data Analytics, Cloud Computing.
- Blockchain is still considered to be a developing technology, despite significant advances in recent years. It is past its peak of high expectations and hype, which has calmed market expectations and helped stakeholders understand that it is not a solution fit to solve any problem; instead, it should be perceived as a tool that can be used under certain circumstances to solve specific problems.
- Benefits offered by Blockchain include transparency, traceability, immutability and distributed trust, making it a strategic technology to consider given the potential impact it has across the industry's three major trends (3D's).
- Private organizations must collaborate closely with the public sector when designing their Blockchain strategies, given that it is the regulatory framework which will ultimately boost or discourage the

adoption of this technology. This can be achieved through regulatory sandboxes or private testing environments where solutions can be showcased to regulators.

- Industry-wide collaboration is also essential for a Blockchain solution to thrive, since benefits are maximized when multiple parties are involved, and a distributed ecosystem is created. The establishment of an industry Blockchain consortium can help lay the foundations for cooperation towards developing Blockchain solutions in Mexican the market.

- Several projects and initiatives are already testing the technology through pilots and small-scale solutions, which can be categorized into 4 broad Blockchain-based business models: Traceability & Transparency, Market Decentralization, Finance & Payments and IoT & Smart Devices.

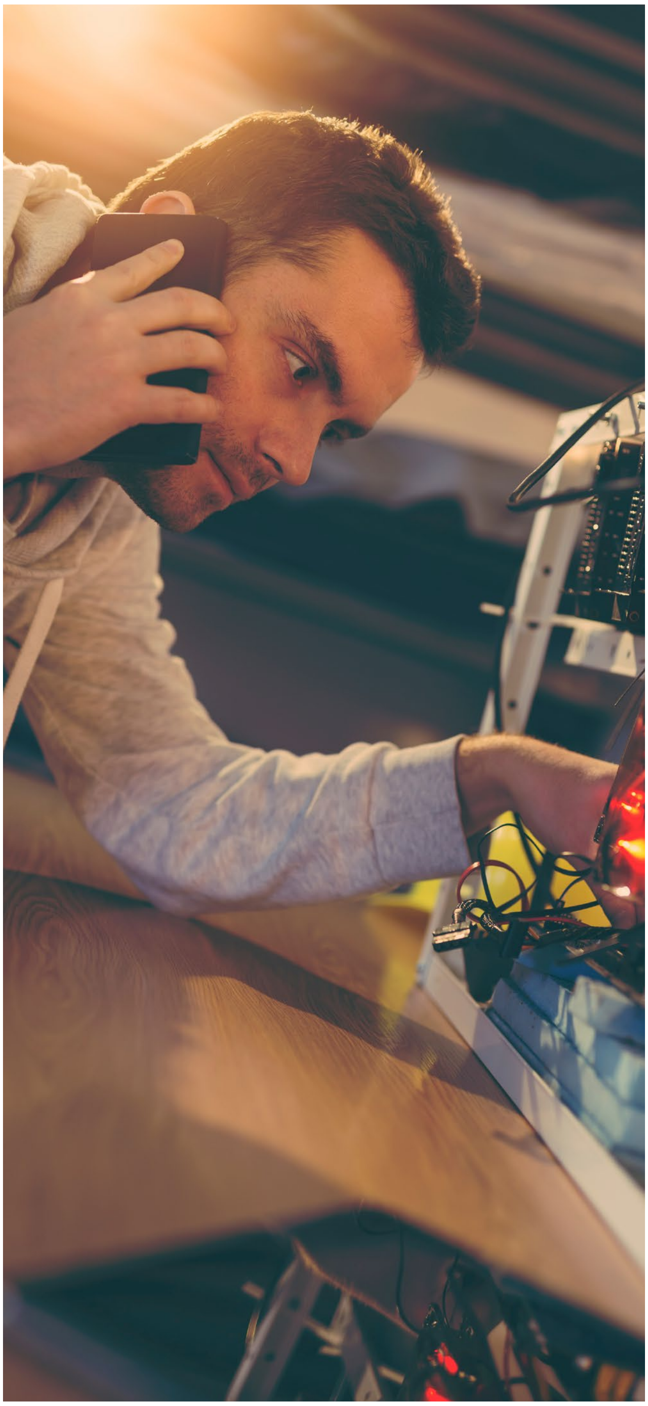
- Three key opportunity areas for Blockchain use cases have been identified for the Mexican Energy Sector:

1. A decentralized CEL marketplace to enhance information transparency and accountability on clean energy generation, while enabling counterparties to trade CELs through a digital platform.

2. Data and information accountability for contract enforcement, permitting users to program smart contracts by leveraging available data to auto-execute certain predefined conditions.

3. A decentralized retail market for industrial parks to buy and sell energy through a digital wholesale energy marketplace in an efficient, transparent and secure way.

This report attempts to serve as a cornerstone for the adoption of Blockchain in the Mexican Energy Sector. The main drivers of this effort is to reduce information barriers regarding this technology, understand the current landscape of how the sector is harnessing this technology at an international level and to provide a set of important considerations and actionable recommendations for stakeholders and industry leaders to evaluate opportunities in this space.




B1
C1

Introduction

1.1 General context and justification of the report

The Energy Sector has proven to be a driver of change for the world throughout history, being one of the most important elements for the evolution of all industries and our society. There has been a continuous transformation of the sector over time, always seeking to provide greater efficiency through the use of the most innovative and revolutionary technologies of each period of time.

Currently, the sector is facing a digital transformation process that aims to improve availability and access to renewable and sustainable energy sources to overcome climate change challenges. The digital evolution that the industry is experiencing today derives mainly from technological disruptions such as Artificial Intelligence (AI), Big Data, Cloud Computing, Mobile Connectivity, Internet of Things (IoT) and Blockchain.

Any industry that is suffering an accelerated rate of transformation will be forced to adopt new disruptive technologies, and Blockchain should be a key area of interest for industry leaders in the world when identifying and designing new opportunities through innovative business models. This is mainly due to its underlying characteristics such as transparency and immutability, enabling distributed trust mechanisms and emerging business models that are defying traditional centralized systems, as is the case of the Energy Sector.

Although there are several fascinating technologies to consider when thinking of digitalization in the Energy Sector, this report will mainly focus on Blockchain due to the impacts its innovative and disruptive qualities can offer to the industry in terms of its major current trends: Decarbonization, Digitalization and Decentralization.

In this sense, Blockchain is a permanent transaction log within a decentralized network that contains chronologically linked information. It enables the management, validation and storage of information, providing efficiency, process automation and streamlining, total transparency in the history of events, immutability of registered information and an auditable trace through a distributed registry.

This system is reliable thanks to its distributed network, meaning that all participants have a complete copy of the registry. Furthermore, the system allows full traceability when registering transaction history in a block, providing detailed information of the operations carried out in previous periods of time. For this reason, Blockchain is an excellent technological tool to promote decentralization and open way to a new economy.

Although this technology was initially created for the management and distribution of Cryptocurrencies (seeking to eliminate centralized intermediaries from current transactional models), multiple industries have identified alternative ways to leverage it, offering multiple benefits linked to its underlying characteristics. This is the case of the Energy Sector, in which significant transformations can be developed, especially if Blockchain is combined with other technologies such as IoT, Data Analytics and AI, allowing the creation of new business models with high impact for the industry.

The global market for Blockchain technology is rapidly increasing, forecasting an approximate value of $23.3 billion US dollars by 2023.[1] Furthermore, Blockchain's global value in the Energy Sector is expected to grow from USD $200 million in 2018 to USD $3 billion in 2025 due to its increasing relevance (Global Market Insights, 2019).[2] This technology is drawing attention from governments, start-ups, utilities, academia and civil society organizations at an international scale. The main reason behind this interest is that it offers vast possibilities for innovative solutions and applications across different sectors, such as: finance, insurance, supply chain, energy, public sector, healthcare and labor markets.

Therefore, the objective of this study is to develop a document with detailed information regarding digitalization of the Mexican Energy Sector, focusing mainly on Blockchain technology. The document will analyze multiple existing and potential use cases in the Energy Sector, aiming to identify the most feasible applications for Mexico. To identify which use cases make more sense in the Mexican sector, and to comprehend Blockchain's potential in the sector, several experts where surveyed, interviewed and invited to participate in specialized workshops, providing valuable inputs, insights, perspectives and an amazing pool of experience to this document.

1. Statista. (2018). Size of the blockchain technology market worldwide from 2018 to 2025. Hamburg, Germany. Obtained from Statista web page: https://www.statista.com/statistics/647231/world-wide-blockchain-technology-market-size/
2. Nhede, N. (2019). Blockchain in energy market to reach $3 billion by 2025. Cape Town, South Africa Obtained from Smart Energy International web page: https://www.smartenergyportal.ch/blockchain-in-energy-market-to-reach-3-billion-by-2025/

Lastly, the study aims to provide industry leaders with a guideline for organizations to identify Blockchain use cases that truly add value to the industry, along with a set of recommendations on how to implement it. This document is considered of high relevance for the Mexican Energy Sector given that digital disruption is forcing organizations to adopt new technologies, and Blockchain remains as a must to consider when developing digital transformation strategies.

The report will include the following key elements:

- General context of the Mexican Energy Sector and relevant market players.
- Basic information regarding Blockchain technology and how it works.
- Market analysis of existing Blockchain applications within the Energy Sector.
- Identification of potential Blockchain use cases for the Mexican Energy Sector.
- General recommendations and considerations to promote the use of Blockchain in the local market.

1.2 Methodology

The methodology used throughout the elaboration of this study revolves around three main components: market intelligence, expert involvement and content development. These activities were executed in parallel due to their high interdependence, in view of the fact that new findings and results in one streamline of work had a direct impact on the other two.

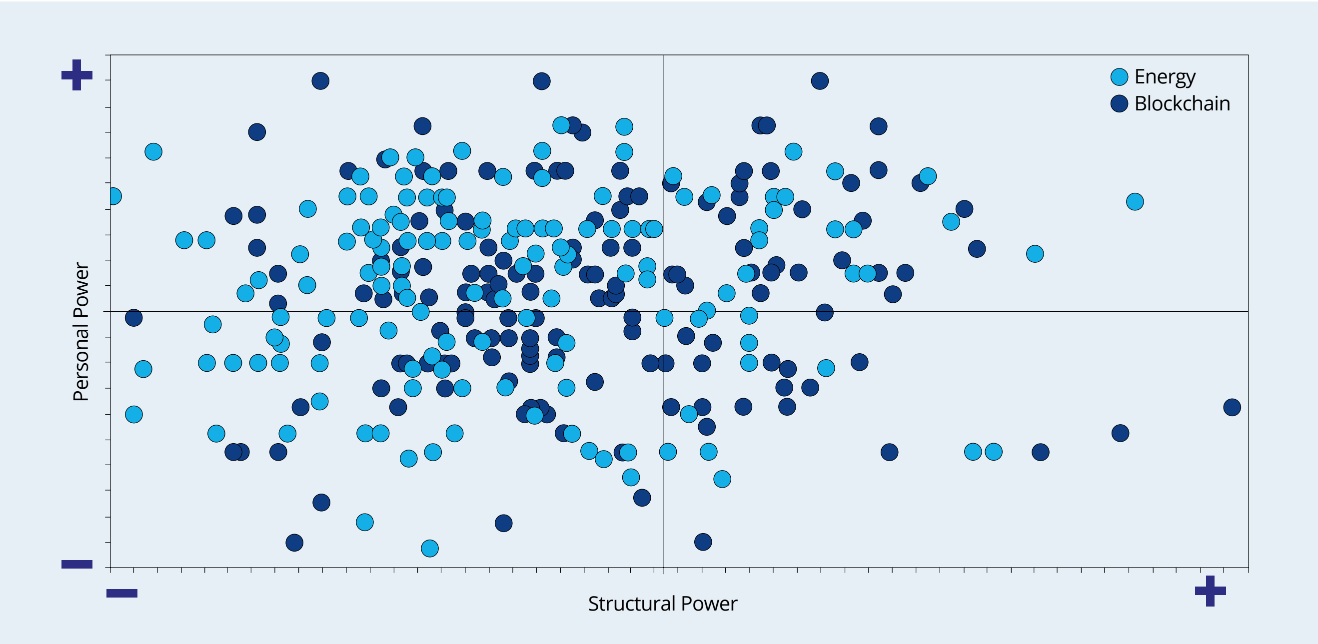
Additionally, addressing such an innovative technology like Blockchain within a highly specialized and technical field, as the Energy Sector, represented a significant challenge in terms of available knowledge, experience and resources. Therefore, the final outcome is the result of an iterative process carried out by a multidisciplinary team from Mexico and Germany, integrated by experts in the Energy Sector, Blockchain technology and digital transformation.

First, a market analysis of the energy industry and Blockchain technology was carried out to obtain an understanding of the market's present situation. In the case of the Energy Sector, the current international and local contexts were evaluated, along with key trends in emerging business models and the role of digitalization in the Energy Transition. For Blockchain technology, an examination of its background and evolution provided key insights to evaluate its maturity and feasibility for suggested use cases in the industry. This gave way to a complete awareness of relevant market players and industry leaders required to be considered for initiatives in this particular topic.

Secondly, subject matter experts were incorporated using criteria designed to identify and select relevant profiles adjusted towards the study's objectives. The areas of expertise included were energy, digitalization and Blockchain. Furthermore, representation from the following relevant fields was considered: private sector, public sector, academia, associations, foundations and startups. Over 300 identified experts were evaluated by analyzing specific variables pertaining their personal and structural power. Personal power refers to the expert's experience and influence within their respective field, while structural power corresponds to the organization they belong to, as well as affiliation to associations or active participation in academic or scientific activities.

Results from this quantitative analysis were mapped out across the two evaluation axes defined to pinpoint outstanding profiles in both quadrants. Two power maps were elaborated, one for experts in energy and the other for Blockchain; the outcome of this exercise can be seen in graph 1.1. Additionally, qualitative elements were also considered for the final expert selection, including profile balance, representation from diverse fields, international and local representation, gender equality, and other external factors not captured by quantitative criteria (e.g. specific strategic roles within organizations).

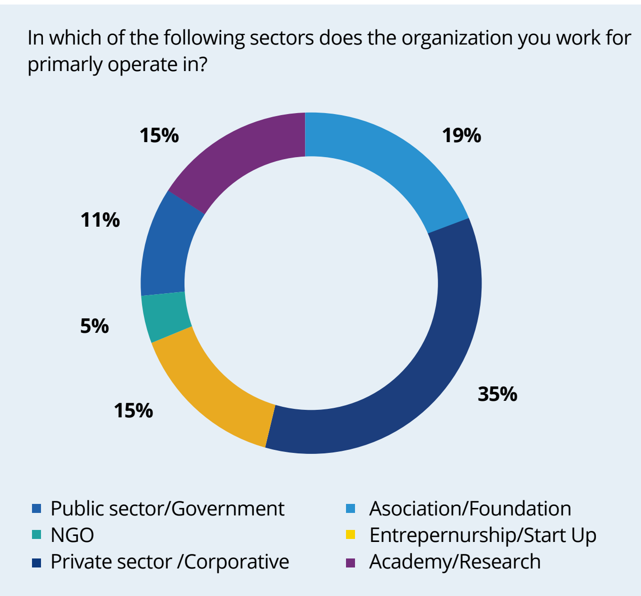
Graph 1.1 – Expert Power Map



Energy Partnership, 2020

Once the expert identification and selection was concluded, a consultation process was initiated to obtain a general landscape of industry leader's opinions regarding the current situation of the energy industry and its adoption of digital technologies, with a particular focus on Blockchain technology. The consultation included 3 relevant areas for the report: Opportunities and challenges, digitalization and Blockchain technology, all centered on the Energy Sector. The consultation survey was sent to over 200 experts, highly diversified in terms of their current role, functional area, field of expertise and sectors they represent, obtaining a 28.36% response rate. A general overview of participating professional profiles is shown in graph 1.2, while graph 1.3 presents expert participation by country.

Graph 1.2 – Expert Segmentation by Sector



Energy Partnership, 2020

Graph 1.3 – Expert Segmentation by Country

Energy Partnership, 2020

Subsequently, over 30 experts were invited to participate in an individual interview to obtain a more detailed perspective of the Energy Sector and how Blockchain technology could impact the Mexican energy market. Each interview was aligned to the experts' archetype and included three sections: challenges, strategic considerations and opportunities, with the objective of promoting a problem driven conversation. The composition of interviewed experts was prioritized to include a well-balanced representation from different relevant stakeholders in the industry, distributed in the following way:

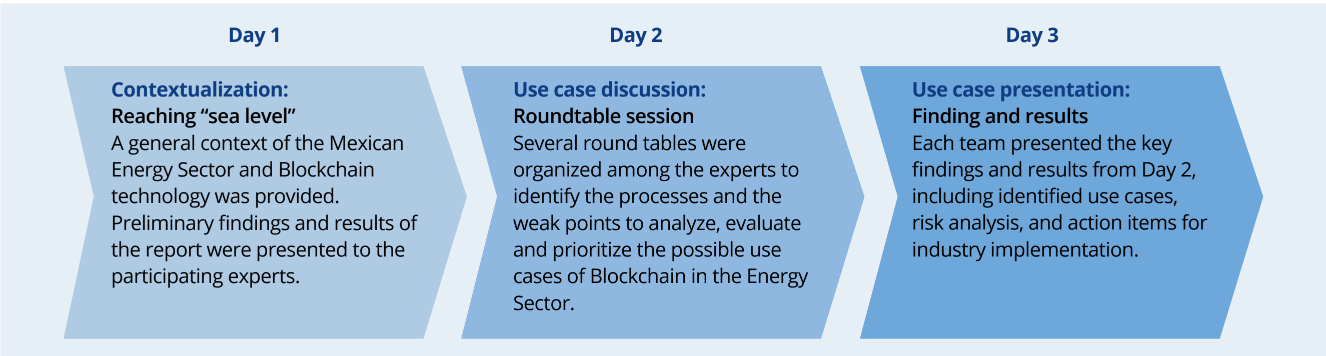
Table 1.1 – Composition of Interviewed Experts

Interviewed experts				
Sector/Area	**Blockchain**	**Digitalization**	**Energy**	**Total**
Private	1	3	4	8
Foundation	2	2	0	4
Academy	1	1	2	4
Startups	6	3	1	10
Asociation	1	2	2	5
Public	0	0	2	2
TOTAL	**11**	**11**	**11**	**33**

Energy Partnership, 2020

All experts who participated in the interview process were invited to a Digital Workshop designed to analyze and qualify Blockchain use cases with high potential for the Mexican Energy Sector. The workshop was divided into a 3-day agenda comprised of the activities shown in graph 1.4. This workshop represented a key milestone for the study, as it was completely centered towards feasible use cases for the Mexican market.

Graph 1.4 – Digital Workshop Framework



Energy Partnership, 2020

All findings and results obtained from the above-mentioned activities were continuously updated and subject to analysis for content development. A first draft was distributed among participating experts as part of the document socialization activities as a mean to receive comments and observations for the final version of the report. This final version is the result of extensive contributions from our participating experts, in-depth research and market analysis of Blockchain technology and a specialized assessment of the Mexican Energy Sector.

1.3 Report Structure

The report is structured in such a manner, so it can help achieve the objective of providing the reader with an understanding and comprehension of the Mexican Energy Sector, Blockchain technology and the potential of Blockchain technology in the Mexican Energy Sector.

The first chapter of the report, "Mexican Energy Sector", provides an overview of the sector and how it works, giving a general context of the main current regulations that govern it, taking into consideration the allowed roles for both the private and public sector. Main recent derived from the Energy Reform are also identified and the electricity value chain is described to provide an understanding of the main activities within the sector.

Afterwards, an explanation on how the Energy Sector is segmented from a supply and demand perspective is given and different clean energy resources are described as the share of the total electricity generation each one represents. Mexico's renewable energy landscape is then analyzed and compared with other countries such as Germany, Italy and the US. A case of best practices regarding renewable energy is explored, featuring Uruguay as a best practice-example for Latin America due to its high renewable energy generation and its similarities with the Mexican Energy Sector.

Section 2.2 goes into detail on the Mexican Energy Sector. First, the main stakeholders in the sector and their roles are described, including commissions, regulators, operators and participating market players. Then, there is a deep explanation of the Wholesale Electricity Market reviewing the objective of its creation as well as each of the products that are traded in it.

The last section from the Mexican Energy Sector chapter discusses the future of the sector. Sustainability and climate change objectives for Mexico are displayed and the current clean Energy Transition in Mexico is analyzed. Then, the future of the regulatory framework is explored to understand the sector's direction. Additionally, there is an explanation about the main trends the Energy Sector is currently experiencing, including decarbonization, decentralization and digitalization; due to the purpose of this report there is a section with special emphasis on digitalization.

Chapter 3 has as its main objective to explain what Blockchain technology is. A definition of Blockchain and a general background is provided, along with a review of the sciences that enable this technology and its main characteristics and functionalities. Then, the origin of Blockchain is revised, followed by its evolution phases and evaluation of its current state across multiple industries, including the Energy Sector.

Section 3.4 covers Blockchain's key principles, explaining what the main components and concepts of the technology are. By breaking down its components, the reader can comprehend the technology in a simplified way. Cryptocurrencies, tokens and smart contracts have a specific section since it is important to review these terms to understand some of the main underlying functionalities of Blockchain. Then, its main benefits, advantages and challenges are explored from a technical, social, regulatory and commercial perspective.

Subsequently, section 3.5 displays the different types of Blockchain platforms, such as public, private and consortium, identifying and highlighting the differences between them. The report then goes into details of consensus algorithms, describing the different consensus mechanisms available and their different functionalities that work towards specific purposes.

Finally, this section provides the reader with key elements for identifying when a Blockchain-based solution truly makes sense and is relevant to consider. This section includes a set of questions that could work as a guide to assess when Blockchain adds value to a specific scenario, along with some examples of general use cases identified for the technology which can help as an initial assessment reference.

Chapter 4, entitled "Blockchain in the Energy Sector", starts by identifying the main relevant actors for Blockchain adoption in Mexico. It specifies roles for the public and private sectors and other organizations worth considering when defining an industry-wide Blockchain strategy. Next, an analysis is conducted to understand the current state of the Energy Sector and to identify opportunities across the value chain, as well as additional technologies that are compatible with Blockchain to identify potential synergies between them. From this section on, most of the insights were provided by experts through surveys, interviews and workshop sessions.

Section 4.4 categorizes different emerging business models in the Energy Sector that leverage Blockchain technology into the four broad groups identified during the market intelligence process. Afterwards, multiple Blockchain application at an international lever are referenced as a benchmark of opportunities for the Mexican market and successful use cases are then provided.

Lastly, potential Blockchain use cases applicable to the Mexican Energy Sector are explored by analyzing them from a general to a more particular perspective. First, current state process flows with significant industry pain points are listed. Secondly, an evaluation of the identified processes where Blockchain becomes a relevant technology to consider is carried out. Next, potential use cases are proposed and prioritized based on an impact-feasibility framework. Finally, the selected use cases are analyzed, including their main benefits, challenges, impacts and risks.

At last, Chapter 5 provides some final key considerations and general recommendations to promote Blockchain implementations in the sector, seeking to give industry leaders guidance and advice for Blockchain adoption in their organizations. The last section summarizes the main conclusions based on vital results and findings of the study, with insights that integrate an analysis from research, surveys, interviews and workshops.

2. Mexican Energy Sector

In this chapter, the Mexican Energy Sector will be explained with special emphasis on the electricity sector. The current landscape of the sector and how it works will be described as well as the main regulations derived from the Energy Reform. This section includes a description of each industry stakeholder and their role, the Wholesale Electricity Market with an explanation of the products traded in it, and the industry's segmentation regarding supply and demand. Later, chapters will focus on clean energy, explaining its definition, its usage in Mexico, trends and sustainability initiatives and objectives. At last, there's a section covering the trends in the Energy Sector, with a brief explanation of each one of them.

2.1 Changes, landscape and international comparison

Recent changes in the Mexican Energy Sector

• Energy Sector before and after the 2014 reform (with focus on the electricity sector)

After several decades of a traditional energy industry model, in 2014 the Energy Reform was approved. Having established a new set of rules, Mexico aimed to become a self-sufficient energy producer. The objective is to reach this desired outcome in the medium- and long-term period, by means of opening energy price competition, maximizing the income derived from these activities, and guaranteeing the economic stability of the country through sustained development, (SENER, 2015).[3]

One of the main reasons behind the implementation of this reform is for the private sector to help in the processing and refining of Mexican resources and to become more efficient through investment and innovation. The objective is for Mexico to stop relying on importing fossil fuels and petrochemicals from other countries, which translates into an increase in energy prices.

Two strategies were created by law to reduce electricity costs and tariffs. One is to offer industrial consumers energy at competitive prices and another to incentivize generators to lower their production costs. For Industrial consumers, the Wholesale Electricity Market was created for them to obtain their energy by buying it from private generators at competitive prices. Generators on the other hand have a methodology to define the price paid for their produced energy, in which the generators with the lowest cost to produce 1MWh are the first ones to be dispatched and so on until the demand is satisfied. The cost per 1MWh of the last generator to satisfy the demand is the tariff at which generators will be paid. With this regulation, generators must lower their costs to increase their margin. This will drive digitalization and the transition to cleaner energies, which are cheaper to produce.

The participation of private companies in the Energy Sector was another significant change. The Mexican Oil Company (PEMEX) and the State utility, Federal Electricity Commission (CFE) are no longer the only market participants and began facing competition from the private sector. Nowadays, they must leverage their competitive advantages and market knowledge in order to remain competitive and thus be successful by growing in the long term.

Nevertheless, private companies cannot participate in every process of the value chain, there are some restricted activities that are reserved for the State. For example, in the oil and gas sector, the private sector can refine, distribute, transport, store and even sell fuels to the public. The upstream activities of exploration and extraction are, however, reserved for the State since all resources found within the nation soil and territory are its property. In the electricity sector the State reserved activities of distribution, transmission and nuclear generation for CFE.

Furthermore, the Energy Reform also changed the role that regulatory entities had. Their activities and responsibilities were redesigned, granting them technical, operative and financial autonomy under a scheme that allows the efficient development of the industry, with a focus on sustainability and anti-corruption rules.

Regarding regulation, a disruptive change in the Energy Sector was the restructure of the National Center for Natural Gas Control (CENAGAS) and the National Center for Energy Control (CENACE), which are independent public institutions responsible of ensuring that companies in the Energy Sector can operate and develop in the market.

CENAGAS is the federal entity responsible of the management, administration and operations of the National Integrated Natural Gas Transportation and Storage System

3. Secretary of Energy of Mexico. (2015). Explicación ampliada de la Reforma Energética. Mexico City, Mexico. Obtained from Mexican Government web page: https://www.gob.mx/sener/documentos/explicacion-ampliada-de-la-reforma-energetica

(SISTRANGAS). It also has the responsibility to guarantee the reliable and safe supply of natural gas allowing the development of sectors which are dependent on this resource.

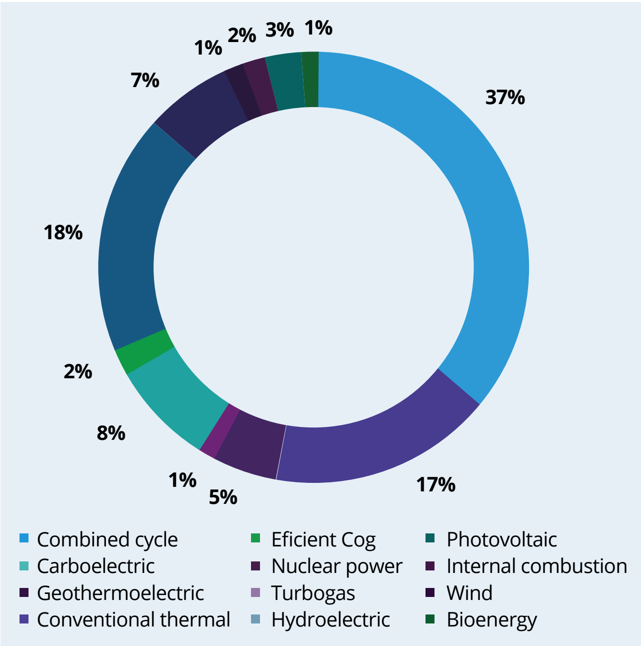
The CENACE is the independent operator of the Wholesale Electricity Market (MEM) and the National Electricity System (SEN), and has the responsibility to efficiently support the transactions of electricity products between generators and consumers, as well as to provide users and participants within the electricity industry in Mexico with an efficient, reliable and sustainable electricity supply in an environmental, social and economic perspective.

Current landscape of the Mexican Energy Sector

• Industry's value and high-level segmentation

The Mexican electricity sector, including its generation, transmission and distribution, was worth MXN $908,476 million (USD $46,350 million) in 2018. It grew 9% with respect to 2017, after two consecutive years of a -1% decrease (INEGI, 2019).[4] The Energy Ministry (SENER) estimates that electricity consumption will increase at an annual average rate of 3.1% from 2018 to 2032, which means an additional 171,536 GWh from the current electricity consumption (SENER, 2018).[5] Below, current installed capacity by technology is shown.

Graph 2.1 – Current State of the Energy Transition



Energy Partnership, 2020

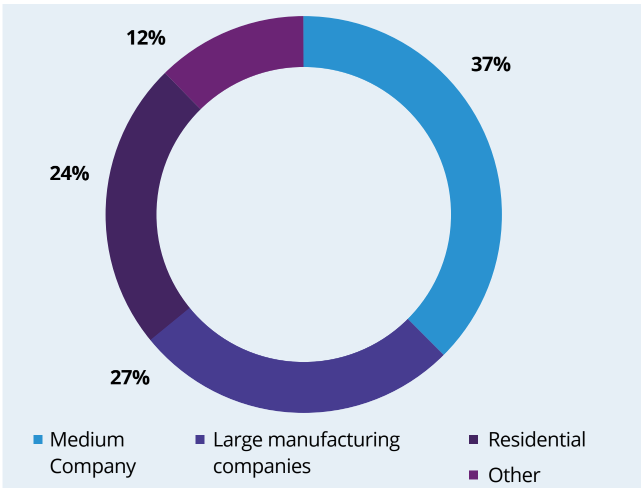
As of December 2018, the generation capacity of the CFE, the independent producers and the rest of permit holders reached a value of 70,053 MW, which meant an increase of 3.1% in relation to 2017.[6]

The most common technology used in Mexico for electricity generation is combined cycle. This technology consists on the generation of electricity from the combustion of natural gas in a gas turbine and it additionally has a steam turbine where the wasted heat goes to produce extra electricity. This generation technology is accounted for 37% of the national capacity, followed by hydroelectric which represents 18% and conventional thermal 17% (SENER, 2019).[7]

Since most of the power in Mexico is produced with natural gas turbines, and 74% of natural gas in Mexico is imported from the United States of America (US), there is a strong dependency on US prices and USD/MXN exchange rate for the price of energy in Mexico.

According to the National Electricity System Development Program (PRODESEN, 2019), the sector with the highest demand for electricity in 2018 were medium companies, consuming 37.6% of the national consumption, followed by large manufacturing companies which consumed 26.6%, and residential with 23.7%. The rest of consumption was by the commercial, agriculture and service sectors. From the sectors above, large manufacturing companies shows the most accelerated growth rate, growing 7.6% over 2017 which is twice as much as the national average (3.8%).

Graph 2.2 – Electricity Demand



Energy Partnership, 2020

4. INEGI. (2019). Mexico City, Mexico. Obtained from INEGI web page: https://www.inegi.org.mx/sistemas/bie/
5. Alexandri, R., Rodríguez, F., Ángeles, A., García, E. & Ramírez, T. (2018). Prospectiva del sector eléctrico 2018 - 2032. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://base.energia.gob.mx/Prospectivas18-32/PSE_18_32_F.pdf
6. CENACE. (2017). Quiénes Somos. Mexico City, Mexico. Obtained from Mexican Government web page: https://www.cenace.gob.mx/paginas/publicas/cenace/quienessomos.aspx
7. SENER (2019), Mexico. Programa de Desarrollo del Sistema Eléctrico Nacional PRODESEN 2019-2033. Sitio web: https://www.gob.mx/cms/uploads/attachment/file/475503/PRODESEN_indice.pdf

Considering all the sectors mentioned beforehand, there were 43.4 million users with access to electricity. The residential sector represents the vast majority, accounted for 88.7% of the total users.

- Types, usage and trends of clean energy within the sector (SEMARNAT, 2018),[8] (LIE, 2014)

Clean energy refers to those energy sources and electricity generation processes whose emissions or residues, if any, do not exceed the thresholds established in the regulatory provisions issued for this purpose.[9]

There are several types of clean energy, some of the main technologies are:

Hydroelectric:
A form of energy that harnesses the power of water in motion, such as water flowing over a waterfall. It is the most widely used renewable energy source in Mexico, since 18% of the total national generation capacity is hydroelectric.

Thermal:
Heat energy is converted into electric power. In most cases, a steam-driven turbine converts heat to mechanical power. In Mexico conventional thermic energy accounts for 17% of the nation's capacity.

Wind power:
Uses wind turbines to harness the power of wind currents. The areas with the highest wind potential are the Isthmus of Tehuantepec, Oaxaca; La Rumorosa, Baja California, and regions from Zacatecas, Hidalgo, Veracruz, Sinaloa and the Yucatan Peninsula. In Mexico, wind power generation represents 6.8% of the total capacity.

Solar – Photovoltaic (PV):
It captures the light emitted by the sun. In Mexico, the total capacity of photovoltaic generation is 1,821 MW, and is mainly located in the north and center of the country. Photovoltaic electricity technology accounts for 2.6% of the national capacity. Nevertheless, it is growing rapidly, since from January to December 2018 solar energy generation increased 583%.

Nuclear:
It comes from splitting atoms in a reactor to heat water into steam, turn a turbine and generate electricity. In Mexico the generation of nuclear energy is reserved for the state and it accounts for 2.3% of the total generation capacity. There is only one nuclear plant in the country, the Laguna Verde nuclear plant, and is located in the municipality of Alto Lucero de Gutiérrez Barrios, Veracruz.

Cogeneration:
Refers to the creation of electricity and heat. Heat can be used to generate additional electricity, 2% of the national capacity is cogeneration.

Geothermal:
Thermal energy generated and stored in the Earth. In Mexico, there are five geothermal fields: Cerro Prieto, Baja California; Tres Vírgenes, Baja California Sur; Domo de San Pedro, Nayarit; Los Azufres, Michoacán, and Humeros, Puebla. Geothermal technology represents 1% of the national capacity.

Biomass:
It originates from biologically renewable matter such as wood, cellulose and charcoal. It can be obtained from the liquid state of that matter, by fermenting sugars, or gas, by anaerobic decomposition of organic matter. Biomass's generation capacity is only 0.5% of the total capacity.

Oceanic:
It is obtained from sea waves, high and low tides and the difference in seawater temperature. Mexico has not been able to develop large-scale generation projects from the oceanic source.

- Explanation of how the Mexican electricity sector currently works

The electricity sector's value chain consists of the following four main sections: generation, transmission, distribution and commercialization.

Generation consists in the transformation of chemical, mechanical, thermal, luminous or any other type of energy into electricity. Nowadays everyone can produce their own energy and either use it or sell it to CFE. In 2018, private companies owned 40.8% of the national capacity. There are several schemes under which privates can generate energy. Each one requires different permits. You can generate for your own supply, to sell the electricity, or if you generate less than 0.5MW and don't participate in the Wholesale Electricity Market you do not even need a permit. Private generators can sell their energy to the CFE, to the Wholesale Electricity Market or through bilateral contracts with qualified users.

8. Secretary of Environment and Natural Resources of Mexico. (2018). ¿Qué son las energías renovables?. Mexico City, Mexico. Obtained from Mexican Government web page: https://www.gob.mx/semarnat/es/articulos/que-son-las-energias-renovables?idiom=es
9. Chamber of Deputies. (2014). Ley de la industria Eléctrica. Mexico City, Mexico. Obtained from Mexican Government web page: http://www.diputados.gob.mx/LeyesBiblio/pdf/LIElec_110814.pdf

Transmission and distribution refer to the transportation of energy from the generation point/source to the final consumer. Transmission refers to the transportation of energy at a high voltage, usually from remote generation plants, into residential or industrial areas. Once electricity complies with the technical requirements, energy enters a substation in which transformers adapt the tension levels. This increases safety, as energy enters the distribution grid and is delivered through residential or industrial areas. These services are provided through the national transmission and distribution grids, which are reserved for the state. However, the CFE could celebrate contracts and form partnerships with private players to finance, install, maintain, manage, operate and extend the national grid with the intention of providing the electricity industry access to companies with the required experience and technology to ensure that the Mexican population has a safe and efficient grid.

The current transmission grid has length of 108,018 km, which means it could go around the world 2.7 times. The National Transmission Network is divided into 53 regions, from which 45 are interconnected and the remaining 8 belong to isolated systems.

Graph 2.3 – Mexico's Transmission System

Transmission regions and capacity

1	Hermosillo	12	Río Escondido	23	Guadalajara	34	Puebla	45	Cozumel
2	Cananea	13	Nuevo Laredo	24	Aguascalientes	35	Acapulco	46	Tijuana
3	Obregón	14	Reynosa	25	San Luis Potosí	36	Temascal	47	Ensenada
4	Los Mochis	15	Matamoros	26	Salamanca	37	Coatzacoalcos	48	Mexicali
5	Culiacán	16	Monterrey	27	Manzanillo	38	Tabasco	49	San Luis Río Colorado
6	Mazatlán	17	Saltillo	28	Carapan	39	Grijalva	50	Villa Constitución
7	Juárez	18	Valles	29	Lázaro Cárdenas	40	Ixtepec	51	La Paz
8	Moctezuma	19	Huasteca	30	Querétaro	41	Lerma	52	Los Cabos
9	Chihuahua	20	Tamazunchale	31	Central	42	Mérida	53	Mulegé
10	Durango	21	Güémez	32	Poza Rica	43	Cancún		
11	Laguna	22	Tepic	33	Veracruz	44	Chetumal		

Energy Partnership, 2020

The next section of the value chain is commercialization, referring to the activity of buying and selling energy. There are companies that supply energy to end users, while there are also marketers that just trade energy without supplying it to any user.

It is established in the Law of the Electricity Sector (LIE) that the end user's access to energy would be through a supplier or self-supply for basic users (households and small businesses with demand lower than 1MW). And in the case of qualified users (Users with demand higher than 1MW and registered in the CRE) it can be through a supplier, self-supply, the Wholesale Electricity Market or bilateral contracts with generators.

Transactions from the commercialization of energy are agreed directly between generators and providers with qualified consumers, while transmission and distribution only charge fees for the use of their infrastructure to the suppliers, whom passes the fee to the final user.

Comparison of the Mexican Energy Sector vs other countries

• Clean energy use comparison

According to the International Renewable Energy Agency (IRENA), in 2018, the global renewable energy capacity was of 2,356,346 MW, which represented a growth of 8% against 2017. Most of this renewable capacity comes from Asia, since 43% of the total renewable capacity is allocated in this region (IRENA, 2019).[10] As renewables have become a compelling proposition, investment into new renewable power has grown from around USD 50 billion per year in 2004, to about USD 300 billion per year in the recent years (IRENA, 2019).[11]

In 2018, Mexico had a total renewable capacity of 22,128 MW, 2,666 additional MW compared to 2017. This means that the total capacity grew by 13.7%, driven mainly by solar and wind power which represent 71% and 25% of the total additional capacity respectively. This significant increase in solar and wind power could be attributed to regulations and cost reductions for renewable equipment. Even though Mexico's annual renewable capacity growth is almost double from the global renewable capacity growth (7.8%), it is still far behind in terms of

10. IRENA. (2019). Renewable Energy Statistics 2019, Abu Dhabi, UAE. Obtained from The International Renewable Energy Agency.
11. IRENA. (2019). Finance & Investment. Abu Dhabi, UAE. Obtained from IRENA web page:: https://www.irena.org/financeinvestment

total capacity from developed countries like Germany, which has a renewable capacity of 120,014 MW, Italy that counts with 53,290 MW or the US with 245,245MW installed. Nevertheless, Mexico is one of the countries that is showing an accelerated growth in its solar energy capacity; in 2018 it grew 279% from 2017, while other countries like Germany, Italy and USA have a solar capacity growth of 8%, 2% and 19% respectively for the same period.

A few years ago, renewable energy technologies were very expensive and only a small niche of customers and investors could take advantage of its benefits. Since 2008 the cost of wind power technologies and photovoltaic equipment has decreased between 41% and 94% making them significantly more affordable. One example is the installation cost for large-scale solar photovoltaic projects, which in 2016 was of $2.08 dollars per watt (W) and in 2018 it fell to a cost of less than a dollar per watt (BANCOMEXT, 2019).[12] Lower costs of renewable energy infrastructure have not only made large-scale projects more attractive, but has also helped individuals and small businesses generate their own energy (known as distributed generation). In Mexico, there are 83,104 contracts for distributed generation, which account for 570.2 MW of installed capacity, representing 0.8% of the total capacity. These small-scale generation projects might help Mexico cover the growing demand for energy and boost the Energy Transition into cleaner sources (CRE, 2019).[13]

In a study conducted by KPMG, in which 21 countries from Latin America were analyzed to identify the renewable energy capacity per capita, Mexico came out in 17th place only under Puerto Rico, Nicaragua, Bolivia and Guyana; while Paraguay and Uruguay were at the top of the chart. This trend may be reverted since Mexico is among the top 3 countries in Latin America for both wind and solar power potential and, as a volcanic region, it also has significant geothermal potential. Therefore, Mexico is one of the top investment destinations regarding renewable energy. According to a report published by the United Nations, Mexico is placed as 14th among countries that have higher investments in renewable energy (BANCOMEXT, 2019).[14]

The potential of renewable energy for Mexico was estimated in the Prospective of Renewable Energy 2018-2032 document published by SENER. Considering regions or areas with high potential for the development and deployment of renewable energy generation infrastructure, as well as a closeness of 20 km or less to the transmission grid, it is estimated that Mexico has a potential to install 32,307,374 MW and a generation of 67,891,324 GWh/y (SENER, 2018).[15] Although it is no easy task, the transmission and distribution grid must be amplified and modernized in order to sustain the accelerated growth of renewable energies. The development of storage facilities and energy batteries will also be fundamental throughout the Energy Transition. These technological developments boost renewable energy adoption (mainly photovoltaic and wind power) since by their nature, they are intermittent, and the electricity produced is not controlled. Demand variations can't be satisfied if generation can't be controlled, therefore storage development will help boost the transition to cleaner energy.

• International best practices

A great example of a country that migrated to a renewable-based energy system is Uruguay, which in 2019 obtained a production of 98% of their total electricity generation from renewable energy sources (Gov. of Uruguay, 2019).[16] This was accomplished by setting strategic factors that helped the transition to clean energy. The main strategic drivers were environmental regulation, strategic role of public companies, sustainability culture, private investment and generation of research, development and innovation for the sector.

Uruguay has a similar Energy Sector to Mexico. Both once had government entities which operated in a monopolistic market which were then changed by a new set of regulations in which private capital was accepted in the Energy Sector, a Wholesale Electricity Market was created, and an organization emerged for the market management and energy dispatch. The legal support for renewables was provided by Decree 354 on the Promotion of Renewable Energies, approved in 2010 by the Ministry of Energy, Mining and Industry (MIEM) of Uruguay.

12. Padilla, A., Chávez, I., García, D., Hernández, G. & Rosalgel, S. (2019). Energías Renovables: Construyendo un México Sustentable. Mexico City. Mexico. Obtained from BANCOMEXT web page: https://www.bancomext.com/wp-content/uploads/2019/01/Libro-Bancomext_Energias-Renovables.pdf
13. CRE. (2019). Evolución de Contratos de pequeña y Mediana Escala / generación Distribuida. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://www.gob.mx/cms/uploads/attachment/file/483322/Estadisticas_GD_2019-1.pdf
14. Bancomext. (2019). México, Lugar 14 de Países con Más Inversión en Energía Renovable. Mexico City, Mexico. Obtained from Bancomext web page: https://www.bancomext.com/notas-de-interes/25160
15. Alexandri, R., Villanueva, E., Muñozcano, L., Rodríguez, F., Rodríguez, J., Ramírez, A., Ángeles, A., García & E. Ramírez, T. (2018). Prospectiva de Energías Renovables. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://base.energia.gob.mx/Prospectivas18-32/PER_18_32_F.pdf
16. Uruguay´s Presidency. (2019). Uruguay cuenta con 98 % de energía renovable y redujo emisiones de gases de efecto invernadero. Monte Video, Uruguay. Obtained from Uruguay+s presidency web page: https://www.presidencia.gub.uy/comunicacion/comunicacionnoticias/ministra-eneida-de-leon-en-sesion-de-naciones-unidas-reduccion-gases-efecto-invernadero

In practice, the government acted to pick winners by establishing aggressive Power Purchase Agreements (PPAs) and tax exemptions (20-100% of income tax, depending on the project) to foster wind and solar generation. Also, the National Administration of Power Plants and Electric Transmissions of Uruguay (UTE) contracted to buy the future production coming from wind farms. To achieve stable demand and prices, private companies could participate in auctions for wind offtake contracts of up to 20 years, which also allowed them to sell surplus power in the spot market. UTE has conducted several auctions for both wind and solar power (IEEFA, 2018).[17]

Uruguay also had a decree (77/006) in which the state's electricity company had to buy a certain amount of renewable energy. This was the first step to the reconversion of the Energy Sector in which private capital was accepted through competitive processes, and incentives for development and investment on national generation were created.

As mentioned before, there are some challenges that come along with having a high percentage of renewable energy generation, mainly wind and solar power, but Uruguay has established a set of options to make the grid more flexible. Such steps include incentivizing flexible back-up generation to balance the variability of wind power, having a flexible hydropower production and using cross-border interconnection to import mainly from Brazil and Argentina; as well as to export generation surpluses when wind and solar power are fully available (IEEFA, 2018).[18]

2.2 Mexican electric sector

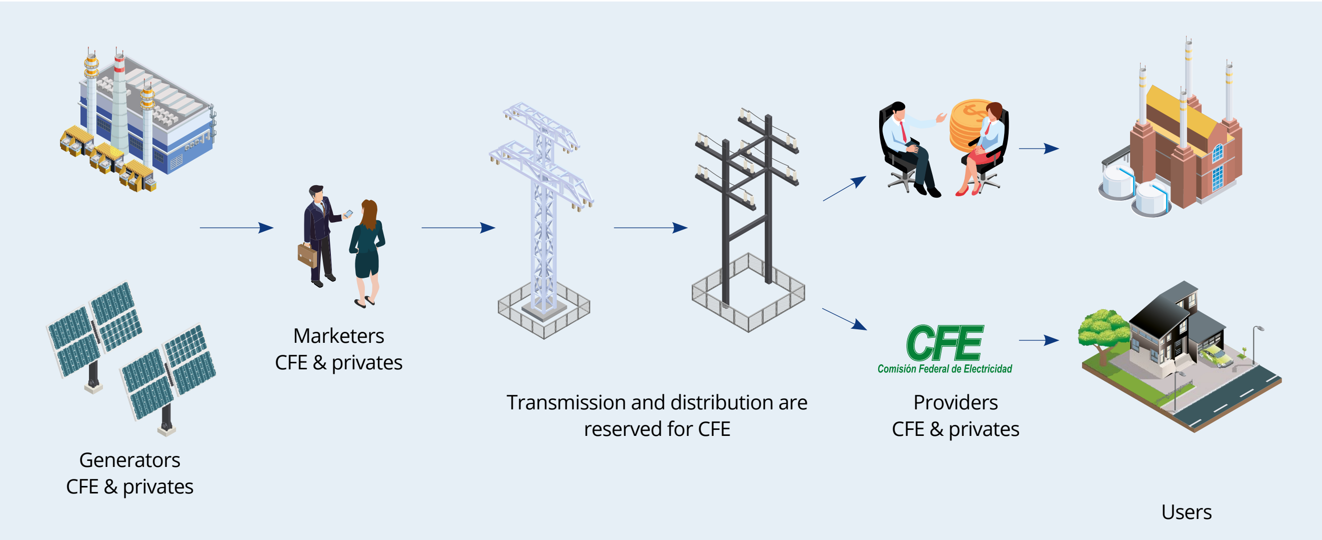
Key stakeholders of the Mexican electric sector

- Brief explanation of Generators, Basic service providers, Marketers and Qualified users

There are different types of players in the Energy Sector with different and specific characteristics. At a high level, they are divided by the activity they are involved in: generators, suppliers, marketers and users.

17. Wynn, G. (2018). Power-Industry Transition, Here and Now Wind and Solar Won't Break the Grid: Nine Case Studies. Cleveland, US. Obtained from Institute for Energy Economics and Financial Analysis web page: https://ieefa.org/wp-content/uploads/2018/02/Power-Industry-Transition-Here-and-Now_February-2018.pdf
18. Wynn, G. (2018). A Renewable Energy Revolution in Uruguay for All the World to See. Cleveland, US. Obtained from Institute for Energy Economics and Financial Analysis web page: https://ieefa.org/ieefa-update-a-renewable-energy-revolution-in-uruguay-for-all-the-world-to-see/

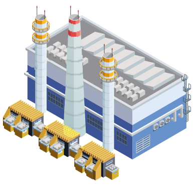
Graph 2.4 – Energy Value Chain in Mexico



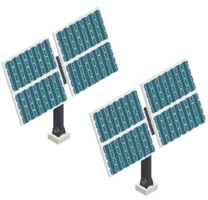
Energy Partnership, 2020

Generators

Private or public entities that own a plant, solar panels or some kind of infrastructure to generate electricity. Generators can be divided into:



- Permissioned Generators:
  Holders of a permit emitted by the CRE which allows them to generate electricity, they have a capacity greater than 0.5 MW and have a contract to participate in the Wholesale Electricity Market. They generate energy to sell it through auctions, to a qualified user, to a qualified service provider or in the spot market.



- Exempt generators
  Those with power plants with a capacity of less than 0.5MW and that do not require a generation permit. They sell their energy to the basic service provider based on the Local Marginal Price (PML) defined by CENACE.

Marketers

They buy and sell energy without producing or providing it to final users

- Non-Provider Marketers
  Companies that are interested in participating in the Wholesale Electricity Market without providing the supply service and only seek to trade energy. Some of the activities allowed by this figure are energy trading transactions and related services, the imports and exports of energy and electric coverage contracts.

Providers

Companies that supply electricity to any kind of user.

- Basic Service Provider
  Provision of electricity services to all the users who do not participate in the Wholesale Electricity Market directly or indirectly. So far, the only basic service provider is CFE.

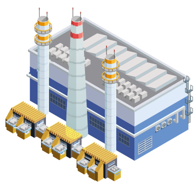
- Qualified Service Provider
  They buy electricity in the Wholesale Electricity Market in order to provide power to qualified users. To obtain required permissions they must first indicate an area of operation, end users and expected sales.

- Last Resort Provider
  Represents qualified users for a limited time, in order to maintain the continuity of the service when a qualified service provider stops providing the electricity supply. In other words, they offer a backup service.

Users

Electricity's final users, considering households, businesses, manufacturing plants, etc.

- Basic User
  Consumers with an electricity demand of less than 1MW. They acquire electricity from basic service providers at a regulated price.



- Qualified User
  Users with a demand higher than 1MW; they must subscribe in the registration of qualified users, unless they received their electricity from the public service before the new law. In this case they have the option to register as qualified user or not.

- Qualified User Participant of the Market
  Qualified users with a minimum demand of 5MW and a minimum annual consumption of 20 GWh can participate directly in the Wholesale Electricity Market without the need to operate through a marketer or provider.

Public sector

Regulatory entities and their function

Various functions and responsibilities were established in the Energy Reform for the regulatory entities of the sector to provide legal certainty to market participants, access to information and to create the competitive conditions for the proper development of the industry.

- SENER
  It conducts the country's energy policy considering hydrocarbons and electricity within the current constitutional framework. Also, it is responsible for guarantying the competitive, sufficient, high quality, economically viable and environmentally sustainable energy supply that the development of the nation requires. In addition, it promotes research in new technologies and is responsible for developing and planning the PRODESEN (National Electricity System Development Program).

- Energy Regulatory Commission (CRE)
  It is an organization under the centralized Federal Public Administration (APF), as a coordinated regulatory body on energy matters.

  The CRE is endowed with technical, operational and management autonomy, and has its own legal personality and ability to dispose of the income derived from the contributions and considerations established for the services it provides in accordance with its attributions and powers.

  This organization is also responsible of regulating and granting the different permits required in the electricity and oil and gas sectors, as well as issuing and applying the tariff regulation. This institution oversees mechanisms for the authorization, review, adjustment and updates of the operational dispositions of the market.

- National Commission for the Efficient Use of Energy (CONUEE)
  Promotes energy efficiency and operates as a technical entity in terms of sustainable use of energy. Likewise, it identifies the best international practices in terms of energy efficiency programs and projects and issues official Mexican standards.

- CENACE
  A decentralized public entity whose purpose is to exercise the operational control of the National Electricity System, operation of the Wholesale Electricity Market and to guarantee impartiality in the access to the National Transmission Network and to the General Distribution Networks.

  As an independent system operator, it performs its functions under the principles of efficiency, transparency and objectivity, meeting the criteria of quality, reliability, continuity, safety and sustainability in the operation and control of the National Electricity System.

  The operation of the Wholesale Electricity Market is carried out in conditions that promote competition, efficiency and impartiality, through the optimal allocation and dispatch of the Power Plants to meet the energy demand of the National Electricity System. Additionally, it is also responsible for formulating the expansion and modernization programs of the National Transmission Network and the General Distribution Networks, which, in case of being authorized by SENER, are incorporated into the PRODESEN.

Description of each CFE division

CFE is divided into 9 different companies, with specific activities assigned to each one.

- CFE Generation
  Generates electric power through the use of any technology in national territory. It is divided into 6 different independent companies.

- CFE Transmission
  Transmission of electric power and other activities related to the financing, installation, maintenance, management, operation and expansion of the infrastructure necessary to provide the public transmission service.

- CFE Distribution
  Distribution of electric power and other activities related the financing, installation, maintenance, management, operation and expansion of the infrastructure necessary to provide the public distribution service.

- CFE Basic supply
  Purchases energy from auctions, wholesale markets, and electric coverage contracts. Supplies electricity to Basic Service Consumers.

- CFE Qualified supply
  Purchases energy from auctions, wholesale markets, and electric coverage contracts. Supplies electricity to Qualified Service Consumers.

- CFE Energy
  Imports natural gas and other commodities from CFE International (US) as well as its local sources of commodities.

- CFE International
  Exports electricity generation inputs (mainly natural gas) to Mexico and sells them directly to CFE Energy.

- CFE Nuclear generation
  Is responsible of the nuclear generation in the country.

- Intermediation of Legacy Contracts
  These contracts are assigned to suppliers and generators during the separation of a vertically integrated company (in this case CFE). By setting a price for the generation of legacy power plants, it assures that large generators don't try to elevate the energy price in their zone (SENER, 2014).[19] This CFE company manages the legacy interconnection contracts, the agreements for the sale of surplus electric power and the other associated contracts subscribed by CFE.

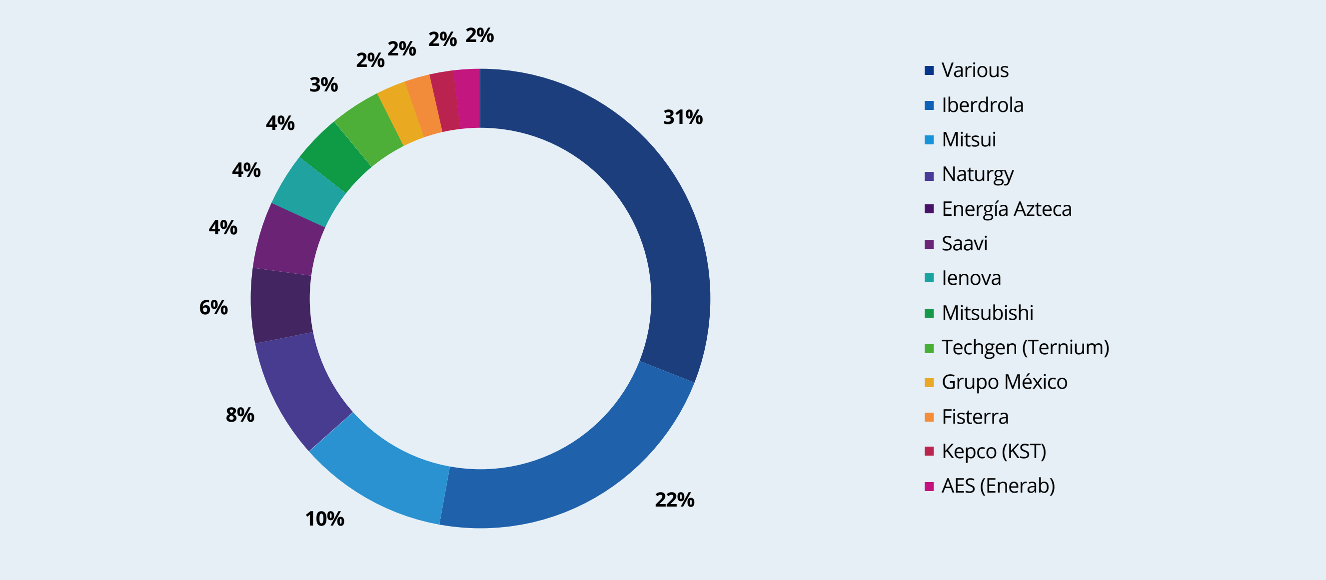
Private sector

• Main generators and their market share

Mexico is a relevant destination for foreign investment in the Energy Sector, many international players have already entered the market due to attractive business opportunities and the potential of renewable energy. Iberdrola is currently the generation market leader, accounting for 22% of the total private generation capacity in the country, followed by Mitsui, Naturgy and Energía Azteca with a share of 10%, 8% and 6% respectively.

19. Undersecretary of Electricity. (2014). CONTRATOS LEGADOS PARA EL SUMINISTRO BÁSICO. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://www.gob.mx/cms/uploads/attachment/file/258356/Nota_explicativa_contratos_legados.pdf

Graph 2.5 - Main Private Generators and their Market Share



Energy Partnership, 2020

• Additional opportunities for privates

The Wholesale Electricity Market opens several opportunities for the private sector and individuals. Some of the main opportunities are found within the electricity generation, as it is not necessary to invest millions to install a large-scale generation plant. Nowadays, a household can install solar panels and consume the energy they produce, or alternatively, sell it directly to electricity providers. A greater investment can lead to large-scale private projects that can operate with different technologies, except for nuclear generation which is reserved for the State.

The private sector can have contracts with the state to provide services to the national grid. These services include the expansion or modernization of the grid, as well as operative and maintenance services. Privates can also buy and sell energy even if they don't produce it themselves and sell it to final consumers.

Wholesale Electricity Market

• Description and objectives of the MEM

The Wholesale Electricity Market (MEM) was created with the main objective of supplying energy at competitive prices so that all users could benefit from acquiring energy at more affordable prices. Those interested in participating in the electricity market can do so under six modalities: as Generator, Qualified User, Provider of Basic Services, Provider of Qualified Services, Provider of Last Resort Services and Non-Provider Marketers, as long as they meet the requirements established by the law.

CENACE, a public and independent organism that does not participate in the market, oversees the Wholesale Electricity Market in order to give certainty and transparency to transactions between industry participants. Transactions include buying and selling energy, Clean Energy Certificates, Transmission Financial Rights, Power Balance and Ancillary Services. Meaning, all products that are required for the optimal and reliable operation of the National Electricity System, and each product has different options in which it can be bought or sold.

• Energy

This is the main product traded in the MEM, it refers to the electric energy produced by the generators. There are different ways to trade energy;

• Short-term market: day-in-advance, hour-in-advance and real-time

In this market energy is bought and sold. It consists of the energy demand of qualified suppliers and qualified users participating in the market and the supply of generators. Transactions carried out in this market are made under the tariffs of the Local Marginal Price (PMLs). The CENACE is in charge of performing the energy dispatch instructions to generate a balance between supply and demand under its responsibility of market operator. There are three categories within the short-term market, these are:

- Day-in-advance market: Offers to buy and sell energy to use the next day
- Hour-in-advance market: Offers to buy and sell energy to use the next hour
- Real-time market: Energy is traded in real time.

- Medium- and long-term auctions

Under this mechanism, buyers provide purchase offers and sellers submit sales offers. The aim of the auctions is to enter into electricity coverage contracts in a competitive way to meet the demand under the most attractive prices and reducing price exposure. Medium-term auctions are valid for three years and there are offers to trade energy and power balance. Long-term auctions have offers for trading energy, power balance and Clean Energy Certificates (CEL) in which the basic user provider signs electricity coverage contracts with generators to buy energy at competitive prices. Nevertheless, public auctions are now suspended until new notice from the Mexican government.

• Power Balance Market

It is a product that generators can sell through the Wholesale Electricity Market. It is defined as the commitment to maintain the generation capacity available for a determined period. The Power Balance Market operates on an annual basis and the power that each generator can sell to the market is defined by the 100 most critical hours of the previous year.

The Load Responsible Entities (ERC) have the obligation to buy power balance from the market; ERC refers to providers, qualified users and generators that participate in the market. The CENACE is the one that determines the amount of power balance that each charge responsible entity must buy.

• Financial Transmission Rights

Financial Transmission Rights (DFT) grant the holder the right and obligation to collect or pay the difference resulting from the value of the Marginal Congestion Components of Local Marginal Prices in two nodes, a node of origin and a node of destiny. It is a mechanism that helps reduce the exposure of the difference in price from one node to another considering the congestion of the transmission grid. Having financial rights of transmission doesn't give the physical right to use the transmission grid. They are calculated based on the Local Marginal Price.

There are four ways in which a company can acquire financial transmission rights; by legacy, through auctions, by bilateral contracts and by funding the grid expansion.

• Clean Energy Certificate (CEL)

One of the objectives of the Energy Reform was to incentivize the investment of new renewable energy generation. The main instrument created to incentivize the investment on renewable energy were the CELs, which are origin certificates given to those generators that produce clean energy; they receive 1 CEL per every MWh of clean energy generated.

By law, every provider, qualified user participating in the market, user with isolated supply and holders of Legacy Interconnection Contracts have the obligation to buy a certain percentage of CELs. In 2020 the percentage is of 7.4%, so the clean energy generators sell their CELs to these players, obtaining an extra source of income as a reward. Market participants can buy and sell offers for CELs at any price they want and buy or sell at the price of any existing offer. With this, the price of each CEL is determined by a supply-demand mechanism.

• Ancillary services

The Ancillary Services are defined as those linked to the operation of the National Electricity System that are necessary to guarantee its quality, reliability, continuity and security, which may include: operational reserves, rolling reserves, regulation frequency, voltage regulation and emergency start, among others, defined in the Market Rules.

The CENACE must calculate the total requirements of the Ancillary Services, considering: the risk of power plant trips, unplanned transmission outputs and variability and forecast errors of intermittent generation and of the load.

• PPA Market

There is another market in which energy and other products from the MEM (e.g. power balance, CELs, Financial transmission rights) can be traded. They're called bilateral contracts, also known as Power Purchase Agreements (PPAs). These are contracts between a generator and a qualified user where a transaction of energy is defined for a determined period and price. PPAs help qualified users have less exposure to the variations on the price of electricity and, on the other side, it helps generator know their future cash flows and assure a steady income.

2.3 Key industry considerations and opportunities

Sustainability and climate change objectives

Paris Agreement

On December 12, 2015, at COP21 in Paris, the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a historic agreement to fight climate change and accelerate and intensify necessary actions and investments for a sustainable future with low carbon emissions. Currently there are 189 parties that have ratified the Paris Agreement, out of the 197 parties of the convention (UN, 2020).[20]

The main objective of the Paris Agreement is to strengthen the global response of climate change threats. For this to become possible, the participants of the agreement have set several goals, procedures, and commitments that will help stop and revert the effects of climate change.

One of the main commitments from this agreement is to limit the increase in global temperature below 2 degrees Celsius, while continuing efforts to limit it to 1.5 degrees, as well as national limitations of Greenhouse Gas Emissions (GGE). Mexico, for example, has agreed to reduce its GGE and black carbon emissions by 25% by 2030. In 2017, Mexico had CO2 emissions of 3.8 yearly tons per capita, which represents a progress from the 4.36 yearly tons per capita emitted in 2008, but there is still a lot of progress to be made to return to gas emissions registered before industrial times (Our World in Data, 2019).[21] For the Mexican Energy Sector to achieve this commitment an increase in energy efficiency and renewable energy generation is required.

There is also an obligation for all parties to periodically report their emissions and their enforcement efforts. There will also be a global stocktaking every five years to assess collective progress towards achieving the purpose of the agreement, and to report on new individual measures of the Parties. Mexico is also part of the Global Geothermal Alliance, which was launched at COP21, and serves as a platform for dialogue, cooperation and coordinated actions between the geothermal industries. The Alliance has an aspirational goal to achieve a five-fold growth in the installed capacity for geothermal power generation and more than two-fold growth in geothermal heating by 2030.

• Agenda 2030

On September 25, 2015, more than 150 world leaders attended the United Nations Summit on Sustainable Development in New York to discuss and approve the Agenda for Sustainable Development. This document includes 17 Sustainable Development Goals (SDGs) aiming to end poverty, fight against inequality and injustice, and deal with climate change without anyone falling behind by 2030.

From these 17 SDGs there is one specific goal for renewable energy, called "Affordable and non-polluting energy". This goal seeks to grant access to affordable, reliable, sustainable and modern energy for all. For this goal to be met, Mexico has committed to take several actions like doubling government investments in innovation and technological development for clean energy by 2020, achieving 99.8% of electrification by 2024 by means of the universal electric service fund, producing 37.7% of electricity with clean energy sources by 2024 and reducing the annual intensity of the final energy consumption to 1.9% from 2016 to 2030.

20. United Nations. (2015). Paris Agreement. Paris, France. Obtained from United Nations web page: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
21. Ritchie, H. & Roser, M .(2019). CO_2 and Greenhouse Gas Emissions. Oxford, England. Obtained from Our World in Data web page: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

• Current state of the Energy Transition[22]

To meet the previous international commitments to fight climate change and become more sustainable, Mexico has established a Transition Strategy to Promote the Use of Cleaner Technologies and Fuels in the Law of Energy Transition. This strategy defines the following planning instruments in the field of clean energy and sustainable use: The Special Program of the Energy Transition (PETE) and the National Program for the Sustainable Use of Energy (PRONASE).

The objective of PETE is to implement actions established in the APF Strategy itself, ensuring its economic viability. It also establishes to pay special attention to the extension and modernization of the transmission grid in areas with high potential for clean energy, allowing their penetration under conditions of economic sustainability.

On the other side, the PRONASE is the instrument through which objectives, goals, strategies and actions are established that will allow the optimal use of energy to be achieved in all the processes and activities of the energy chain, from exploitation to final use. The six objectives on which the Program is based to promote energy efficiency in the country are:

- Development of energy efficiency programs
- Create an energy efficiency regulation
- Establish cooperation mechanisms between public, private, academic and social organizations[23]
- Strengthening of institutional capacities
- Foster an energy saving culture
- Invest in technological research and development

According to the last publication of the Clean Energy Progress Report published by SENER, until June 2018, Mexico generated 17.3% from renewable energy and 6.8% from other clean energy sources. This means that in 2018 Mexico generated 24.12% of its electricity from clean sources, missing only 0.88% to meet the Energy Transition goals. This is a significant increase considering that in 2016 only 19.6% of the electricity generation came from clean sources.

Solar power is the renewable-based generation source with the highest adoption in recent years in Mexico, growing at an exponential rate. In 2016, the solar power generation was of 215 GWh while in 2017 it was of 1,150 GWh, and in the first semester of 2018 the solar generation was 5 times the generation from the first semester of 2017.

Wind power has also seen an accelerated growth in the last years, since 98% of the current installed wind power capacity has been developed in the last 6 years and the generation in the first semester of 2018 was 19.6% higher than in the same period of 2017.

Sector's direction in regulatory terms

President Andrés Manuel Lopez Obrador (AMLO) has made several statements regarding the Energy Sector in Mexico. The President mentioned that CFE will play a major role on the distribution of electricity in the country, so it can fulfill its social function, but it will not be a monopoly. He stated that, for the government, it is a priority to invest in the Energy Sector to promote national development and obtain energy self-sufficiency.

One of the main strategic objectives the current government has established is to strengthen the CFE for it to maintain its competitiveness against the private sector, and this is planned to be done through public investment. AMLO pointed out that the federal government will invest in the modernization of over 60 hydroelectric plants to potentiate current available infrastructure and make it more efficient, due to them being a renewable and low-cost source of energy (El Financiero, 2018).[24]

The administration's perspective towards the Energy Reform is that it will remain in force, nevertheless there are some particularities which may change.

Trends and challenges of the Mexican Energy Sector

• Trends in the Energy Sector

There are trends that have influenced the electricity sector since the beginning, for example the ever-growing and changing demand of energy. Before, a household would only need electricity to light some bulbs, and maybe a radio, but the number of devices that constantly consume electricity has increased drastically. Besides the increase in electricity consumption by household, the population growth has also been an important factor to the increase in electricity demand. Recent trends are also reshaping the Energy

22. Beltrán, L., Villanueva, E., Muñozcano, L., Rodríguez, J., Ramírez, M., Portepetit, A., Ramírez, A., Rocha, D., Avila, D., Lourdes, M., Rangel, R., Ramones, F. (2018). Reporte de avance de energías limpias. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://www.gob.mx/cms/uploads/attachment/file/418391/RAEL_Primer_Semestre_2018.pdf
23. Secretary of Energy of Mexico. (2016). Programa Nacional Para Aprovechamiento Sustentable de la Energía. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://www.gob.mx/cms/uploads/attachment/file/185047/PRONASE2016OdB04112016concomentariosCCTE_0812116CSVersionFinalcomprimida.pdf
24. Hernandez, A. (2018), Autosuficiencia energética de México no se dará a corto plazo: AMLO. Mexico City, Mexico. Obtained from El Financiero web page: https://elfinanciero.com.mx/nacional/cfe-generara-competencia-con-proveedores-de-energia-para-abaratar-tarifas-lopez-obrador

Sector, these trends are known as the "3Ds" and consist of decarbonization, decentralization and digitalization.

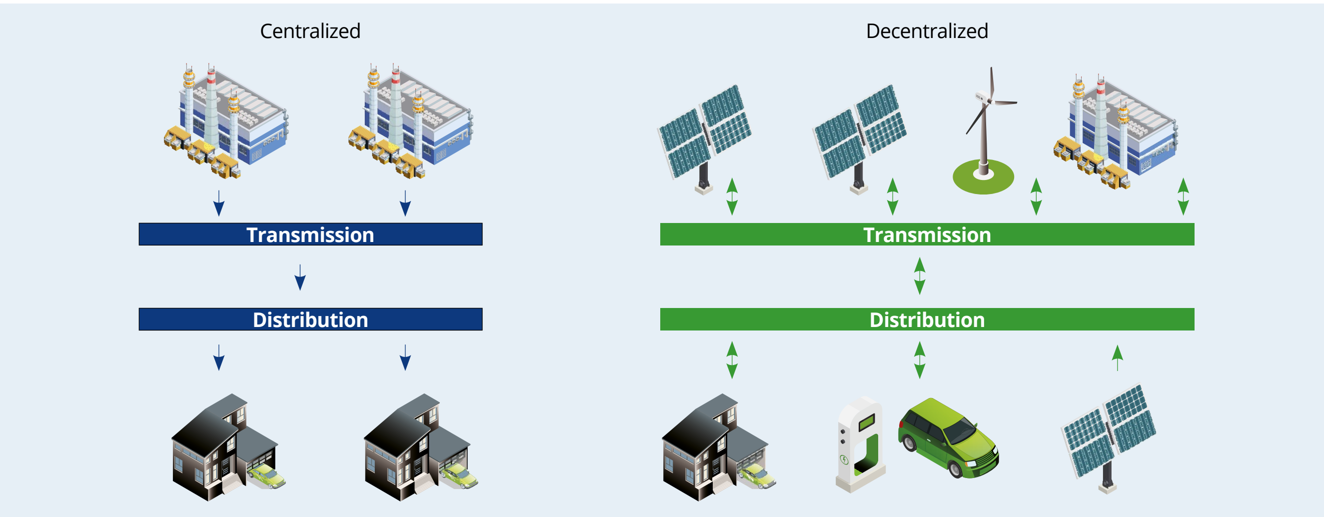
Decarbonization refers to the reduction of Greenhouse Gas Emissions such as CO2 or CH4. The United Nations (UN), The Organization for Economic Co-operation and Development (OECD), as well as local governments, have been trying to incentivize and foster initiatives to help the world and the economy decarbonize. The use of renewable energy is key to reduce the emission of greenhouse gases because no fossil fuels are needed to produce electricity. With the reduction of greenhouse emissions, global warming can be reduced through the mitigation of irreversible negative impacts on global climate.

Digitalization on the other hand is a process that involves the adoption of new digital technologies to the electricity sector. Important elements of digitalization such as sensors, supporting software and data applied to the current structure and operation of power systems can provide a series of improvements, helping to reduce costs and increase efficiency across the electricity value chain. Digitalization applied to all types of power plants, as well as for transmission and distribution networks, offers an array of opportunities to improve performance for the benefit of individual companies, the system as a whole, energy consumers and the environment. The connectivity component of digitalization has the potential to reshape the power sector by connecting power supply with key demand sectors such as transport, buildings and industries. The International Energy Agency (IEA) estimates that the overall savings from these digitally enabled measures could be in the order of USD 80 billion per year over 2016-2040 (IEA, 2017).[25] One important aspect to have in mind when talking about digitalization is that with the ever-growing quantity and detail of data, cybersecurity, privacy and data security concerns become of significant relevance.

However, the labor side of the industry must also be considered for digitalization to truly thrive, there is currently a lack of knowledge required to implement digital strategies in the Energy Transition. Angélica Quiñones, president of ANES, argues that a shift of paradigm is needed to incentivize the industry towards new jobs that will be arising in the sector. Instead of viewing new technologies as a threat, they must be seen as an opportunity of jobs created throughout this process; otherwise the sector will have an inefficient labor force with an excess supply of workers with obsolete skillsets and a scarce pool of available human capital with the demanded technical and functional competencies in a digitalized industry.

Lastly, decentralization refers to the change in structure of the sector, passing from one where a few centralized power plants generate most of the electricity to one where there are many distributed generators, known as Distributed Energy Resources (DERs), that produce small quantities of energy (such as PV panels in rooftops). This shift results in an increasing amount of companies competing throughout the electricity value chain.

Graph 2.6 - Centralized vs. Decentralized Models



Energy Partnership, 2020

25. International Energy Agency. (2017), Digitalization & Energy. Paris, France. Obtained from International Energy Agency web page: https://webstore.iea.org/download/direct/269

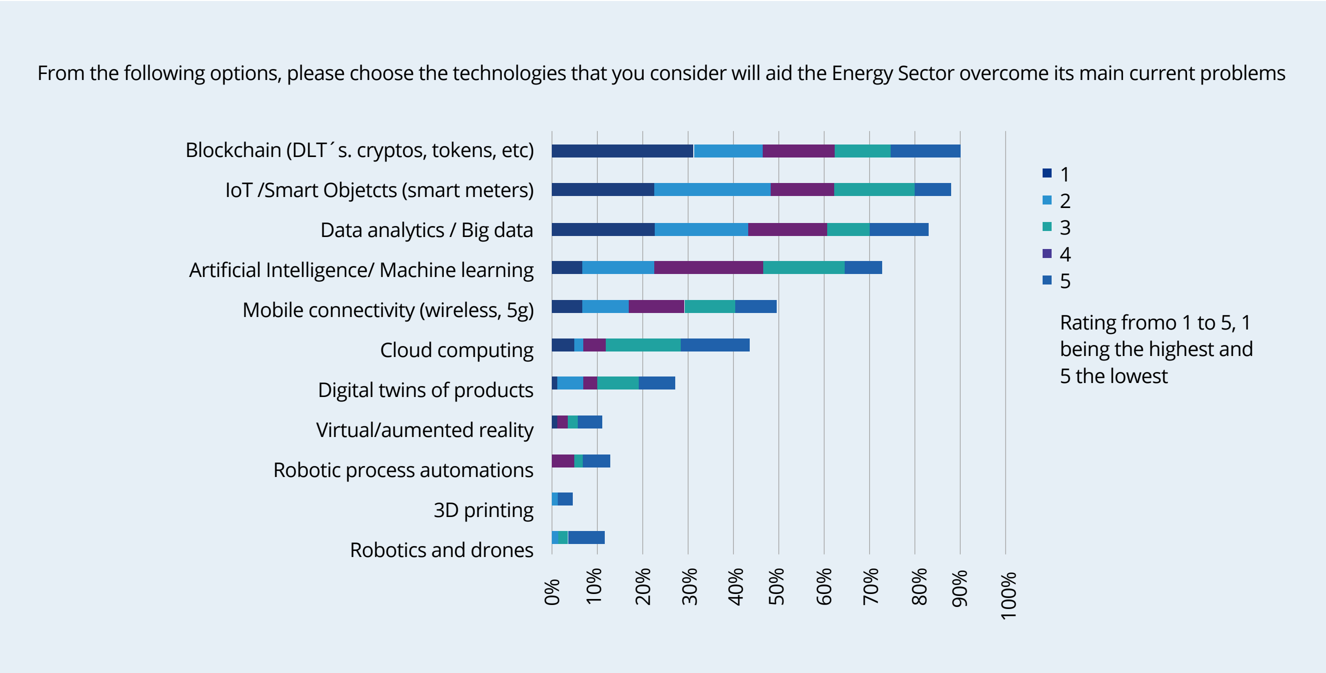
This process has a variety of benefits for the electricity sector. For example, distributed generation decreases the grid's congestion since electricity is produced in the same place where it is consumed, incentivizing local consumption and reducing the need to use the transmission and distribution networks. This will avoid energy losses that occur throughout the grid, helping relieve congestion points and making it more flexible. It will also help supply energy for marginalized population in which the distribution infrastructure may be limited. Nevertheless, decentralization still has some challenges such as the increasing complexity of the grid and the market. With consumers turning into prosumers, CENACE has to monitor the exact quantity of energy consumed from the grid and calculate it on the different rates on which the transactions occur. This will require a smart and efficient operator to manage and monitor the huge amount of information being produced; this can be achieved by leveraging decentralized technologies such as Blockchain.

Digitalization in the Energy Sector

• Technological advances and opportunities in the sector

There have been various technological advancements that have helped the Mexican electrical grid be safer and more dynamic while maintaining a secure supply. Consulted experts were asked which technologies they consider will aid the Energy Sector overcome its main current challenges, where they had to select 5 digital technologies from a list of options and rate them on a scale from 1 to 5, 1 being the most relevant and 5 the least. The obtained results are shown in the following chart, followed by a description and a general context of each technology:

Graph 2.7 - Technologies to Consider for Digitalization of the Sector



Energy Partnership, 2020

Experts consider that the most relevant technology to aid the Energy Sector overcome its problems is Blockchain. Chapter 3 provides a deep analysis on Blockchain technology and its main functionalities. Below, other technologies that experts consider relevant in the Energy Sector will be described.

The Internet of Things (IoT):

Describes the network of physical objects (things) that have integrated sensors, software and other technologies in order to connect and exchange data with other devices and systems over the Internet. These devices range from everyday household objects to sophisticated industrial tools. It is estimated that in 2019 there were 26.6 billion devices connected to the internet and it is expected to rise to 75.4 billion in 2025 (CD-Center, 2020).[26]

26. Muykim, C. (2020). The Internet of Things (IoT): The Network of Networks. Phnom Penh, Cambodia Obtained from Cambodia Development Center web page: http://cd-center.org/wp-content/uploads/2020/02/P127_20200210_V2IS1.pdf

As power systems become more complex and decentralized, IoT applications enhance the visibility and responsiveness of grid-connected devices. This technology is a pillar for smart grids, which are fundamentally an electricity network that can intelligently integrate the actions of all users connected to it, in order to efficiently deliver sustainable, economic and secure electricity supply.

Features of smart grids include the controllable two-way flow of electrical power, the automated, bidirectional flow of information and even automatic dispatch systems. Smart meters, for example, monitor power consumption in real-time, dynamically calculate spending and share data between end-users and utility companies. This data helps the operator tailor demand-response programs and adjust pricing. Users, on the other hand, can control their electricity usage at a granular level, responding to load changes and limiting energy waste.

Innovations range from smart thermostats, which help maximize energy efficiency by adjusting the temperature of consumers' homes depending on whether they are at home or not, to specialized sensors that enable a remote monitoring and management of all distributed energy resources.

In summary, IoT is the state of connectivity between devices that allows them to exchange information and interact with each other. IoT and Blockchain can create synergies when applied together, as Blockchain requires data collection points due to input and register information in a decentralized and immutable way.

- Big Data:

Refers to extremely large datasets, both structured and unstructured, as well as its processing and analysis. The industry analyst Doug Laney defined big data as datasets with the 3 Vs; Volume, Velocity and Variety. The added value of Big Data is not defined by the amount of data that you gather, but in the way you exploit that information to create value.

The electricity sector is a clear example of extremely large amounts of available information that needs to be managed, including transactions, generation from each power plant or DERs, the performance of the power grid, the consumption of each user, and in some cases even of each device. Therefore, Big Data has been used widely in the Energy Sector. Nevertheless, there is still untapped potential to increase the amount and

quality of data, to later analyze and obtain benefits for each company and for the sector as a whole.
One example of the presence of Big Data in the electricity sector is when power generation companies recollect vast amounts of data to create analytics models that help them predict the future price of energy, allowing them to plan and adjust their operational model to face challenges or increase profit. Big Data is also required in the management of the national electricity system, due to the large volumes of information generated within it. Since storage systems are not commonly used in the national power grid (in the case of Mexico) it is important to be able to match supply with demand. This represents a challenge since it is difficult to accurately determine how much to produce when consumption levels are unknown. Big Data can help forecast power consumption by analyzing the consumer's historic behavior and the factors that drove that behavior.

Big Data can contribute with analytical functions in which the information fed into the Blockchain is used to find insights and create value. On the other hand, Blockchain can complement Big Data to avoid erroneous information derived from double spending, data manipulation and cyberattacks. An important consideration highlighted in the survey "State of Data Science and Machine Learning" is that the challenge data professionals consider most relevant is dirty data (Kaggle, 2017).[27] Blockchain does not solve the issue of dirty data, it only provides immutability and transparency over registered data. In other words, if captured data is of low quality, then the Blockchain registry will not be reliable (garbage in – garbage out principle), as it will offer an immutable and transparent version of dirty data. Valuable synergies between these two technologies will only be achieved if the data entering the chain is clean from the initial collection point.

• Artificial Intelligence:

AI is referred to as an area of computer science that focuses on the creation of intelligent machines that work and react similarly to humans. It refers to systems that, in response to data observed, collected and analyzed, change behavior. Artificial Intelligence can help optimize the time to respond to changes, thus reducing costs and risks.

For example, electricity transformers are devices incorporated within the power grid to adjust the voltage up and down at both ends of the transmission and distribution lines. These transformers, as any other device, may present a malfunction that can cause dangerous failures on the grid, since they contain large amounts of oil in direct contact with high voltage components, increasing the risk of fire and explosions (IIENG, 2015).[28] Sensors in the grid could notify irregularities in the transformers and conduct actions automatically, saving time and decreasing risks. AI will act based on the information it receives and may shut down operations or even activate a backup transformer if available. Therefore, AI can help define actions based on information being introduced into the Blockchain, while leaving an auditable and trustworthy database.

• Mobile connectivity:

This technology will allow organizations and their customers to have accountable information delivered anytime, anywhere, and flowing through a vast number of platforms and/or devices. To accommodate this exponential growth in demand, communication providers are rolling out next-generation connectivity technology (5G), including wireless and wireline densification, edge computing, and software defined networks. For power and utilities providers, these investments can enable greater speeds, faster reaction times, and more flexibility in network architecture. Ben Hertz-Shargel stated in an interview that communications through 5G networks will allow for the connection of more devices that will participate in the system, granting higher visibility of what happens in the grid by reporting situational awareness of the market and enabling smaller resources to participate.

• Cloud computing:

Cloud computing is the delivery of computing services, including servers, storage, databases, networking, software, analytics, and intelligence, over the Internet to offer faster innovation, flexible resources, and economies of scale. It provides features such as: creating cloud-native applications, delivering software on demand, streaming video and audio, unlimited compute power, advanced analytics capabilities and the ability to store, back up and recover data.[29] The main differen-

27. Kaggle. (2017). Kaggle ML & DS Survey A big picture view of the state of data science and machine learning. California, US Obtained from Kaggle web page: https://www.kaggle.com/kaggle/kaggle-survey-2017
28. Tariq, S., Affzal, R & Zia, A. (2015). Transformer Failures, Causes & Impact. Bali, Indonesia. Obtained from International Conference Data Mining, web page: http://iieng.org/images/proceedings_pdf/8693E0215039.pdf
29. Microsoft Azure. (2019). What is cloud computing?. Washington, US. Obtained from Microsoft web page: https://azure.microsoft.com/en-in/overview/what-is-cloud-computing/#uses

ce between the cloud and Blockchain is that in the cloud the information is stored in a centralized data set while in Blockchain every participant has a real-time distributed copy of the information.

• Digital Twins:

They are software representations of assets and processes that are used to understand, predict, and optimize performance in order to achieve improved business outcomes. Digital twins consist of three components: a data model, a set of analytics or algorithms, and knowledge. Some of the benefits behind this technology are: improved production, lower maintenance costs and reduced risk.[30]

• Robotic Process Automation:

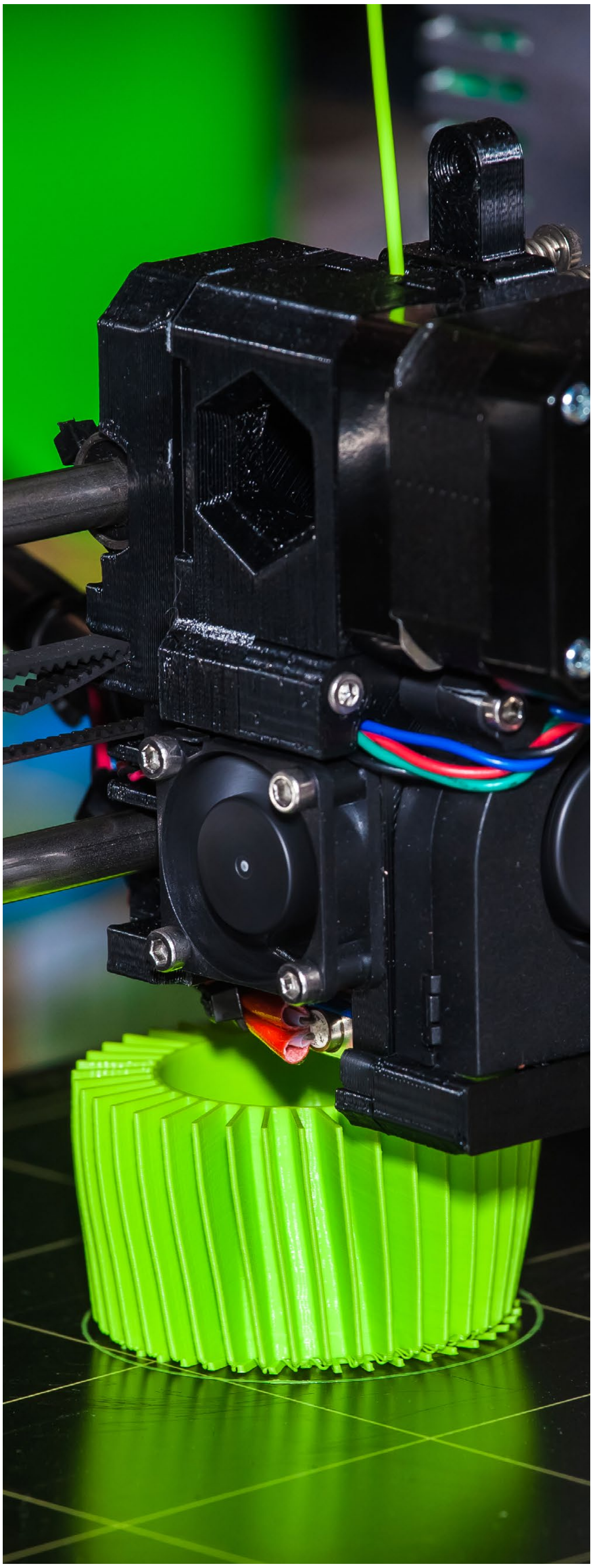
Robotic Process Automation (RPA) is the term used for software tools that partially or fully automate human activities that are manual, rule-based, and repetitive. They work by replicating the actions of an actual human interacting with one or more software applications to perform tasks such as data entry, process standard transactions, or respond to simple customer service queries. It frees humans from monotonous, low-value-added tasks and makes them available for higher-value tasks that require human creativity, ingenuity, and decision making.[31]

• Robotics and drones:

Power utilities are increasingly using robotics to handle the inspection of risky, time-consuming, and hard to reach assets, as well as maintaining those assets and improving their operations. Robots and drones now play a crucial role in the power utilities space in areas such as operations and maintenance (O&M) and asset inspection, leading to savings on O&M costs.[32]

• Virtual / augmented reality:

Virtual reality is when a person is placed in a computer-generated world. The idea behind virtual reality is that you are separated from the real world and experience the virtual world as being real. In augmented reality, on the other hand, the real world is augmented by computer-generated content. An



30. GE Digital. (2019). Digital Twin, Digitize assets and processes to enable better industrial outcomes. California, US. Obtained from General Electric web page: https://www.ge.com/digital/applications/digital-twin

31. Aiim. (2020). Intelligent Information Management Glossary. Maryland, US. Obtained from Aiim web page :https://www.aiim.org/What-is-Robotic-Process-Automation#

32. GlobalData Energy. (2019). Power utilities are placing their trust in robotics, reveals GlobalData. United Kingdom. Obtained from Power technology web page: https://www.power-technology.com/comment/power-utilities-are-placing-their-trust-in-robotics-reveals-globaldata/

example of how utilities could use this technology is by providing employees with virtual training programs in which the computer generates a virtual situation and employees learn to response without real world risks.[33]

• 3D printing:

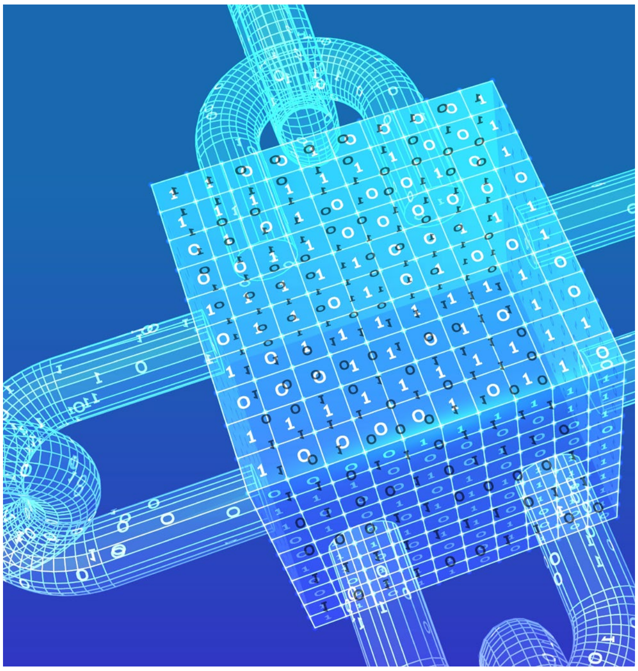
Three-dimensional (3D) printing is an additive manufacturing process that creates a physical object from a digital design. The process usually works by laying down thin layers of material in the form of liquid or powdered plastic, and then fusing the layers together. 3D printing can create custom, complex parts faster than traditional manufacturing processes. Engineers have found the technology to be a perfect solution for low-volume projects.

The greatest benefits are obtained when these technologies work together and complement each other. The integration of these technologies into the grid by creating synergies that allow for two-way communication between the utility and its customer and enhanced sensing along the transmission lines is known as smart grid. The constant real-time communication between consumers, utilities and equipment allows the system to manage and monitor the consumption, generation and even failures on the grid.

It is estimated that digitalization in the Energy Sector will reduce the costs of operation and maintenance by 5%, decrease total network losses by 5% , boost efficiency by increasing the electricity output per unit of fuel by 5% and potentially extend the lifetime of power plants and networks by 5 years (IEA, 2016).[34]

Similarly to how operation and maintenance costs have a trend to decrease, costs of renewable equipment show the same behavior, allowing individuals and small businesses to start generating their own energy by installing solar panels on their rooftop or even small-scale wind power equipment. This infrastructure requires a two-way grid and two-way meters, called smart meters, which measure energy consumed and the energy produced. The function of these smart meters is not just to measure electricity, but also to register real-time consumption of electricity without requiring a utility employee to verify the consumption directly on-site. The penetration of smart meters in Mexico is still immature due to their high price, but as more people produce their own energy, the use of smart meters will increase.

When talking about the future of the electricity sector it is important to mention the role of electric vehicles. In Mexico, sales of hybrid and electric vehicles increased 92% from the first semester of 2018 to the same period of 2019. The penetration of electric vehicles will represent a considerable increase in electricity demand. According to a report by the IEA in 2018 the consumption of electricity from EVs was of 58 TWh and it is expected to reach 640 TWh in 2030 (IEA, 2019).xxiii Nevertheless, it is probable that rather than seeing EVs and the electrical grid as separate things, they will work as a whole. EV fleets can create vast electricity storage capacity by acting as decentralized storage resources, as well as to act as flexible loads capable of providing additional flexibility to support power system operations. With smart charging, EVs could adapt their charging patterns to flatten peak demand, fill load valleys and support real-time balancing of the grids by adjusting their charging levels. The use of EVs as a flexibility resource via smart charging approaches would reduce the need for investment in flexible, but carbon-intensive, fossil fuel power plants to balance renewables (IRENA, 2019).[35]



33. Bakker Elkhuizen. (2020). What are virtual and augmented reality?. Vugth, Netherlands. Obtained from Bakker Elkhuizen web page: https://www.bakkerelkhuizen.com/knowledge-center/what-are-virtual-and-augmented-reality/
34. International Energy Agency. (2017). Digitalisation and Energy. Paris, France. Obtained from International Energy Agency web page: https://www.iea.org/reports/digitalisation-and-energy
35. IRENA. (2019). Innovation landscape brief: Utility-scale batteries. Abu Dhabi, UAE. Obtained from International Renewable Energy Agency.

Digitalization is helping the sector adapt to new trends and changes in demand, nevertheless there are still some challenges to overcome. Such is the case for energy storage, which has seen some development but still isn't used in large scale since it is still very expensive and might not be feasible to install it in the national grid. Batteries will have a great impact in the power sector from the grid-side point of view as well as for the consumer. Utility-scale batteries will allow the grid to be more stable, relief the congestion of transmission and distribution lines, be used as black start services, and have a flexible ramping. Utility-scale battery storage systems can also enable greater penetration of variable renewable energy into the grid by storing the excess generation and by firming the renewable energy output.

From the consumer point of view, batteries called "behind the meter batteries" which are connected to the meters of residential, commercial and industrial consumers, will help manage the energy consumption and energy injection to the grid. Some of the benefits that behind the meter batteries would bring is the increase of self-consumption from renewable energy, backup power services and cost savings on electricity bills.

Digitalization is not a result, but a process. This means we still have much to see from the future challenges in the sector and the technological advancements that will help us overcome them. One particular technology that stakeholders and business are currently interested in due to its high potential is Blockchain. Blockchain's global value in the Energy Sector is expected to grow from USD $200 million in 2018 to USD $3 billion in 2025 due to its increasing relevance (Global Market Insights, 2019).[36]

36. Nhede, N. (2019). Blockchain in energy market to reach $3 billion by 2025. Cape Town, South Africa Obtained from Smart Energy International web page: https://www.smartenergyportal.ch/blockchain-in-energy-market-to-reach-3-billion-by-2025/

3. Blockchain Technology

Blockchain technology is creating a new playing field for innovation with use cases across multiple industries, enabled by existing technologies such as the internet, cryptography, computational power and cloud computing. It is a powerful tool for the upcoming digital economy. Several sectors and organizations have begun to experiment with this technology in response to shifting paradigms in social and economic interactions within an increasingly globalized and digitalized world.[37] One of the main trends seen by these changes are emerging business models oriented towards decentralization, making Blockchain a likely tool to impulse them.

3.1 General Background

Distributed Ledger Technology (DLT) is a more robust term that refers to the distributed storage and governance of data on a shared ledger, which enables the exchange of value (represented through public or private information) between network participants in a digital environment. Blockchain is a DLT subset, with its own technological aspects regarding data storage and ledger integrity structures. This report will use the term Blockchain interchangeably with DLT while referring to distributed ledgers in general, seeking to maintain popular terminology.

Attention around Blockchain is focused on shifting traditional business models that are highly centralized and dependent on third parties, aiming to provide new means of trust to transactions occurring between multiple entities. Transforming current trust models, Blockchain offers a new mechanism to validate the exactitude and authenticity of transactions by using distributed ledgers. This functionality eliminates out-of-sync ledgers along with the need of transaction settlements, reducing risks derived from incomplete or fragmented information that can result in multiple versions of the truth.[38] This, in other words, can be referred to as the Blockchain "single source of truth".

Although great potential has been linked to Blockchain technology, it is still considered to be a developing technology. There have been significant advances in recent years, however, most industries remain at an experimentation phase where tests and pilots are being deployed to identify prominent use cases and demonstrate successful applications. Tangible qualitative and quantitative benefits have been shown in several pilot projects that aim to transform centralized business models that predominate in current economic, politic and social spheres around the world. The Energy Sector is not the exception, as it has also begun to explore several use cases using Blockchain technology.

3.2 Technology Conceptualization

Enabling components of Blockchain technology

A first approach towards understanding Blockchain technology is to think of it as a "mix" of 3 enabling sciences behind the main functionalities of distributed ledgers: cryptography, game theory and software engineering.[39] Although these sciences have been studied independently from each other, the arrival of Blockchain managed to harmonize specific characteristics of each field to help unleash this innovative tool.

- Game theory:
  Allowed the creation of incentive mechanisms that enable a trusted decentralized network by rewarding participants that engage in correct/truthful behaviors. This was achieved by studying the Byzanthine Generals Problem, which describes a situation where multiple parties must coordinate themselves and agree upon a unique strategy to avoid failure in a shared objective, while acknowledging the existence of corrupt/unreliable parties.

- Cryptography:
  Grants security, privacy and immutability into transactions executed within the distributed network through a process known as "hashing", which generates a cyphered code that acts as a unique digital fingerprint in the shared ledger (see section 3.4). This allows participants to verify and validate information

37. Vigna, P. & Casey, M. (2015). The Age of Cryptocurrency: How Bitcoin and the Blockchain are challenging the Global Economic Order. US: New York Times. Pg. 277
38. KPMG International. (2018), Blockchain and the future of finance: A potential new world for CFOs – and how to prepare. Obtained from KPMG International, pp. 2.
39. Mougayar. W. (2016). The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology. New Jersey, US.; pp. 11.

on the ledger without requiring the exposure of its details.

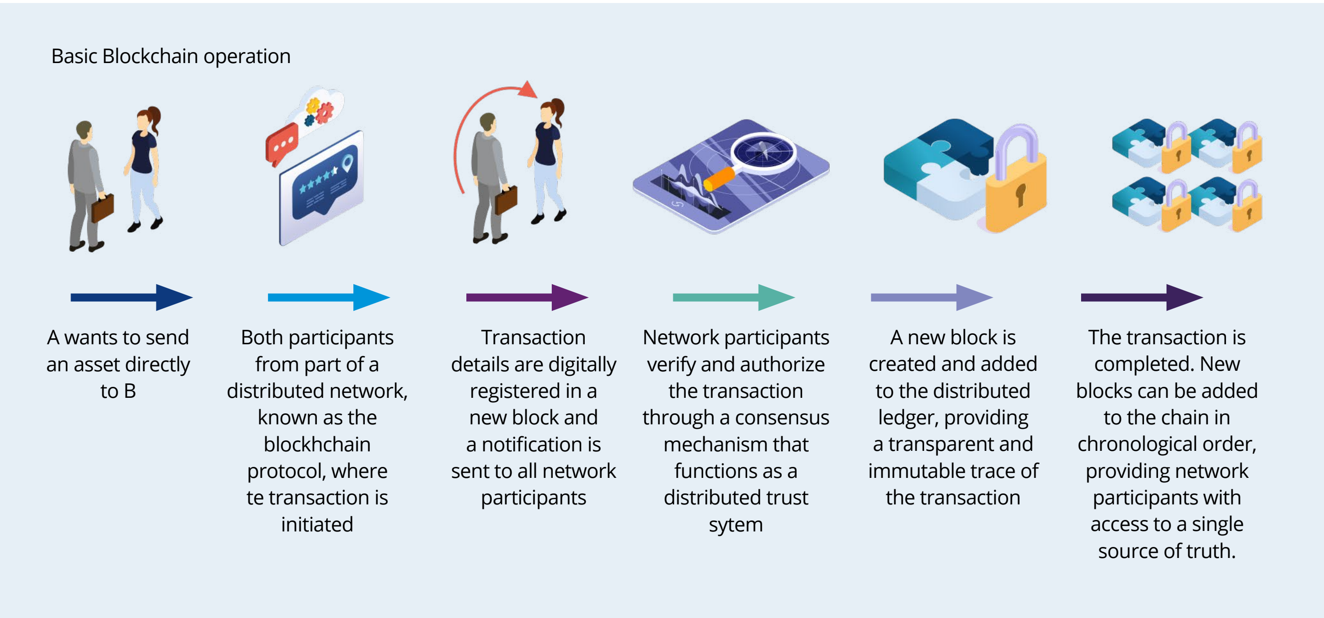
- Sofware Engineering:
  This is the key component for combining game theory and cryptography into a distributed network of participants known as nodes, further building upon prior Peer-to-Peer (P2P) network technologies. The network updates and maintains information on the ledger remotely through computational power with a software program known as the Blockchain protocol.

Basic understanding of Blockchain's functionality

In traditional ledgers, trusted third parties or authorities manage information incoming from multiple sources to update changes regarding its origin and destination within a given system. This type of model has been used as a mean to provide trust between individuals and entities by controlling information flows and accessibility to it. Financial institutions have used this model to control monetary transactions, while the energy industry has used it when monitoring energy supply and demand, tracking of energy generation and consumption, keeping records of payments, maintaining updated information on assets and other circumstances that involve interaction between multiple participants.

Blockchain seeks to offer an alternative method to obtain trustworthy records amongst multiple parties without the need of a centralized third party. The previous components reviewed are what enables this network-based trust mechanism to function in a distributed way, meaning that each participant possesses a copy of the ledger.[40] Therefore, a consensus mechanism is established for participants to keep the ledger updated and synched (see section 3.5), resulting in a unique and shared version of the truth that provides immutability and transparency to the information. To better understand how Blockchain works, a simple peer-to-peer transaction with a basic cryptoasset is depicted in Graph 3.1.

Graph 3.1 - Basic Blockchain Understanding



Energy Partnership, 2020

Introduction to Blockchain technology

Blockchain is not a synonym of Bitcoin, nor is it limited to cryptocurrencies. Although it is true that Bitcoin laid the foundations for Blockchain, it must be understood only as a particular use case enabled by this technology. Blockchain is a distributed ledger with applications beyond cryptocurrencies, enabling new trust mechanisms for information registry between multiple parties; said information can be related to transactions, ownership, agreements or other relevant events that require trust between the engaging parties.

However, the underlying value behind Blockchain doesn't reside in transferring information. When comparing Blockchain technology to the internet, the latter can

40. Allende, M. (2008). Cómo desarrollar confianza en entornos complejos para generar valor de impacto social. Washington, DC, US. Obtained from Inter-American Development Bank. pp. 7

be conceived as a tool that enables information transfer (text, images, videos, etc.) between individuals, while Blockchain becomes an additional layer on top of the internet that allows individuals to assign value to said information.

Hence, the technology mainly serves as a trust mechanism, where initial applications revolve around transfer-of-value in the form of money (cryptocurrencies like Bitcoin), intellectual property, contracts, patents or even physical assets exchanged in a digital world such as utilities. This is why multiple industries, including the Energy Sector, have identified applications and new business models based on Blockchain that could potentially transform current state processes, increasing efficiency, security and transparency.

3.3 Current State

Blockchain beginnings

The birth of Blockchain can be traced back to several predecessors in the 90's that contributed to the development of this technology. Understanding the enormous impact and high relevance the internet would have in our world, a group of cryptographers known as "cypherpunks" showed strong concerns regarding data privacy, information security and individual empowerment.

They developed tools that would allow pseudo-anonymous interactions through cryptographic privacy, seeking one shared goal: information privacy for an increasingly digital world.

Blockchain evolution

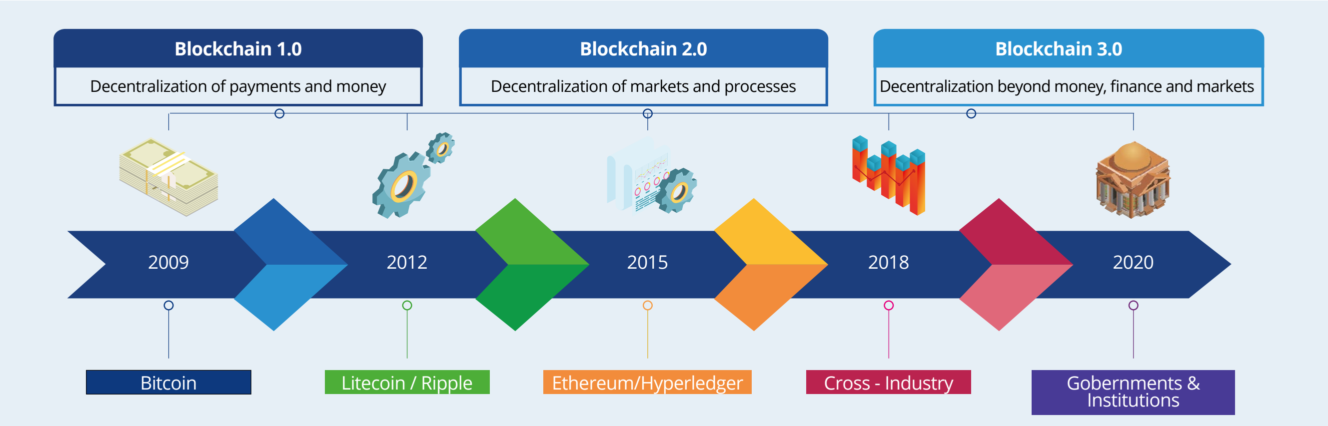
Since the arrival of Bitcoin in 2008, the technology has continued to evolve by adding layers and functionalities throughout the technology's development. To further understand the increasing interest from multiple fields it is helpful to review Blockchain's main technological developments, which Melanie Swan has identified in three main stages:[41]

• Blockchain 1.0: Decentralization of payments and money. A form of digital money known as cryptocurrencies was the first application of Blockchain technology, enabling individuals to carry out online transactions without relying on a centralized third party to act as an intermediary. Examples include remittances, cross border payments, peer-to-peer money transfers and digital payment systems.

• Blockchain 2.0: Decentralization of markets and processes through smart contracts. The addition of programmable codes capable of auto-executing transactions within a Blockchain network enabled more complex applications beyond cryptocurrencies. Prominent use cases are Tokens, Initial Coin Offerings (ICO's)/ Security Token Offerings (STO's), loans, bonds, financial instruments and process automation.

• Blockchain 3.0: Decentralization beyond money, finance and markets. Understanding Blockchain's underlying characteristics allowed for new distributed ledger models to emerge, such as private and permissioned networks. Multiple industries continue to gain interest in the technology as a promising tool to reconfigure traditional business models. Sectors that stand out in exploring uses with Blockchain technology are banking & finance, insurance, logistics, government, health and energy. [42]

Graph 3.2 – Blockchain Evolution



Energy Partnership, 2020

41. Swan, M. (2015). Blockchain: Blueprint for a New Economy. United States of America: O´Reilly Media Inc.
42. Swan, M. (2015). Blockchain: Blueprint for a New Economy. United States of America: O´Reilly Media Inc.

Paradigmas importantes: Bitcoin y Ethereum

It's impossible to understand the current state of Blockchain, along with its uprising popularity that sparked great interest and hype throughout the world, without first talking about two popular Blockchain protocols today: Bitcoin and Ethereum. However, these platforms should not be perceived as synonyms of Blockchain technology, but rather as useful and powerful tools for specific use cases.

• **Bitcoin:** Considered to be the origin of Blockchain technology, causing a worldwide furor that overshadowed the full potential of the technology. Previous attempts to create digital money represented the foundations for the whitepaper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System", published in 2008 by Satoshi Nakamoto, an anonymous author whose identity is still unknown today.

A set of cryptographic and technological innovations constitute the 4 main principles that made Bitcoin the first successful attempt of digital money in the market.[43] First, it enables peer-to-peer transactions between individuals. Second, it doesn't rely on a third party (i.e. financial institutions) for transaction record keeping, thus eliminating the double spending problem previous digital currencies presented. Third, cryptography enables a consensus mechanism for authorizing and validating transactions between network participants, without requiring a centralized system to provide trust amongst individuals. Lastly, trust is placed into the network, which is decentralized and distributed throughout participants.

Bitcoin continues to be the most pervasive cryptocurrency in the market, representing 64.75% of total market capitalization of all circulating cryptocurrencies.[44] There are three main factors behind the success of Bitcoin that previous attempts could not accomplish:

- Mixing the right ingredients: Leveraging knowledge from previous projects, along with the innovative "Proof-of-Work" consensus mechanism that solved the double-spending problem, granted credibility to Bitcoin as an alternative and reliable transaction method.

- Technological development: Significant advances in computational power made it possible to develop the required capabilities for a distributed network of nodes to function. Additionally, mainstream use of mobile devices (laptops, tablets and smartphones) allowed users to interact in a digital economy with less friction.

- Cultural and social context: Increasing internet activity has intensified network effects for digital based business models, further engaging individuals in the digital world. This has raised awareness regarding information privacy and cybersecurity issues. Furthermore, the 2008 financial crisis threatened the traditional financial system, resulting in reduced market trust and strengthening alternative systems such as cryptocurrencies.

• **Ethereum:** This innovative Blockchain protocol enhanced the technology with the use of smart contracts, permitting the creation of Tokens and Decentralized Applications (DApps) through its own quasi-Turing-complete programming language. This new functionality revolutionized Blockchain's potential with applications beyond transaction and information recordkeeping, allowing the technology to evolve into use cases that were inconceivable before.

Decentralized services developed on the protocol are powered by Ethereum's own Token: the Ether (ETH). It serves as a payment method within the network for transaction processing purposes. In other words, it is the underlying cryptocurrency that is used to keep the network running. When a user interacts with Ethereum's Blockchain a fee must be paid. Said fee is calculated in "gas", which refers to a unit measure used to quantify the computational effort employed for executing operations in the Ethereum network; the calculated gas is always paid in ETH.

The integration of binary programming codes inside the Blockchain enables Ethereum based applications to manage and execute transactions in an autonomous way based on a series of pre-set conditions that must be accomplished. Moreover, it allows users to create their own Tokens for multiple purposes, such as a fundraising mechanism through Initial Coin Offerings (ICO's) (further information in section 3.4). These functionalities are what make of Ethereum a key phase of technological development that further fueled the hype and expectations behind Blockchain.

Both Bitcoin and Ethereum represent milestones for Blockchain due to their technological innovations. It is worthwhile to mention that these protocols also have short comings such as scalability, energy resource requirements and high volatility in their main underlying

43. Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Obtained from web page: https://bitcoin.org/en/bitcoin-paper
44. Information obtained from coinmarketcap.com on June 29, 2020.

cryptoassets, which can represent an adoption barrier for some business cases. These issues have contributed to the development and adoption of alternative DLT architectures that are designed to fit specific scenarios and necessities, varying according to the use case being evaluated.

The promise of disrupting industries with high levels of centralization and strong dependency on third parties is already visible in the financial and public sectors. The Energy Sector is another case where Blockchain is being explored as a potential tool for transitioning towards new business models. As mentioned in section The future of the Mexican Energy Sector, the industry's main trends today are Decarbonization, Digitalization and Decentralization (the 3D's), hence Bitcoin and Ethereum serve as clear examples as to how Blockchain is a relevant tool to consider for at least 2 out of the 3 trends

Blockchain technology current landscape

Bitcoin market acceptance, along with the emergence of smart contracts, has generated a technological hype, reaching its peak during late 2017 and early 2018. Potential applications across multiple industries were identified and high expectations were placed on innovative solutions for recording any event considered of importance to humanity, such as: ownership titles, patents, birth/death certificates, election votes and medical records.[45]

However, after the cryptocurrency crash in early 2018, accompanied by the uncovering of several ICO frauds and unmet project promises, a phase of disillusionment calmed market expectations. Thus Blockchain is no longer perceived as a universal remedy by all industries, but rather as a technological tool that can be leveraged under certain circumstances to solve specific problems.

Major trends and applications today revolve around information transparency, traceability and security. In 2019 different fields adopted Blockchain technology as an innovative solution to improve existing services and business models. For instance, implementations for banking, insurance, supply chain and digital identities are currently the most advanced. However, other sectors like health, energy, government, media and education increasingly continue to explore solutions involving digital currencies/tokens, smart contracts and other DLT´s in an effort to enhance process efficiency and customer experience. Ben Hertz-Shargel mentioned

45. Tapscott, D. & Tapscott, A. (2016). Blockchain Revolution: How the Technology behind Bitcoin is Changing Money. US: Portfolio.; pp 7.

during an interview that he is skeptical of Blockchain as a comprehensive platform for transactions and business logic, particularly when performance, scale, and privacy are key concerns. However, he does recognize the value of Blockchain in a more narrow, fiduciary role, enabling multi-party trust of a transaction platform, when no intermediary can provide that trust.[46]

The financial sector is a clear example of an industry challenged by a traditional centralized system, forced to adapt their infrastructure towards digitalization, including Blockchain-based solutions. Cryptocurrencies remain as the top trending topic in this field, due to their decentralized characteristics that unlock alternative business models. The energy industry is similarly transitioning from a highly centralized system to more complex distributed models which will require digitalization and market decentralization to thrive.

Increasing interest can also be seen in the public sector. Nearly all Central Banks have centered their attention towards low volatility cryptoassets known as stablecoins, initiating conceptual and theoretical research in CBDC's (Central Bank Digital Currencies), with pilot projects being deployed by countries like China, Sweden and Uruguay.[47] Involvement from governmental bodies is key for Blockchain solutions to gain traction, seeking to impulse transparency, inclusion and innovative business models.

Fields where the government is particularly interested include: health, energy, identity and communications. The use of smart contracts is another focal point for Blockchain technology. The insurance industry has made significant efforts to leverage this functionality to develop new business models based on digital solutions. One example are automated claims, using smart contracts and AI to increase efficiency and improve customer experience throughout the notification, validation, investigation, resolution, settlement and closure processes. Similar self-enforced rules can be programmed into processes within the energy industry value chain in order to eliminate unnecessary third-party interaction, increase efficiency and mitigate risks.

Most use cases related to the energy industry today are still under experimentation and testing phases, however there are already some advanced applications. Leading solutions are related to origin and attribute certifications, driven by the transparency and traceability features Blockchain offers. Some examples include certificates for renewable energy production, energy efficiency goals, carbon emissions and clean energy consumption. Other solutions that have shown great potential include peer-to-peer energy trading at both retail and wholesale levels, data and asset management for real-time grid and infrastructure monitoring, asset backed tokenization for utilities trading, project finance, payments, billing and settlements. Further information on Blockchain based business models for the energy industry can be found in Chapter 4: Blockchain Technology in the Mexican Energy Sector.

Blockchain platform current landscape

It's already possible to see successful Blockchain applications at a cross-industry level, where multiple applications and use cases can be translated into different platforms, varying on the overall objective and functionalities enabled by each protocol in order to achieve specific goals. The following table shows relevant platforms to be considered for Energy Sector related use cases:

46. Hertz-Shargel, B., Livingston, D. (2019). Assessing Blockchains Future in Transactive Energy; Atlantic Council, Global Energy Center; pp 44.
47. Barontini, C., Holden, H. (2019). Proceeding with caution – a survey on central bank digital currency. de Bank for International Settlements Sitio web: https://www.bis.org/publ/bppdf/bispap101.pdf

Table 3.1 – Blockchain Platforms

Platform	Objective	Characteristics	Common uses	Use Case in the Energy Sector
Bitcoin	Decentralization of payments through an electronic version of cash which facilitates peer-to-peer transactions.	• Public • Bitcoin Cryptocurrency • Pseudonymous	• Peer-to-Peer transactions • Store of value • Speculative investments	Token rewards for solar energy prosumers can be traded into Bitcoins and other popular cryptocurrencies
Ethereum	The first general-purpose smart-contract platform, allowing programmable capabilities for building decentralized applications	• Public • Ether Token • Programmable	• Token creation • DAO's / Dapps • Equity sales / fund raising • Decentralized markets • Cryptocurrency wallets	Ethereum based applications leverage Blockchain technology and IoT devices to offer consumers the possibility of purchasing energy directly from the grid rather than from retailers
Hyperledger Fabric	A private Blockchain enabled as a general-purpose smart contract platform for developing solutions with a modular architecture	• Private/consortium • Permissioned membership • Protection of digital keys and sensitive data • Programmable	• Supply Chain • Interbank transfers • Medical Records • Equity Issuance	IBM created the first Blockchain-based green asset management platform on the Hyperledger Fabric platform to help enterprises develop carbon assets in a more efficient way
Corda	A private open source Blockchain platform developed by R3 that enables businesses to engage in direct transactions through the use of smart contracts and a privacy model which allows information security	• Permissioned • Smart Contracts • CorDapps • Secure and private • Highly Scalable	• Financial Instruments • Derivatives trading • Digital assets • Digital identity • Global Trade / Supply Chains • Insurance and healthcare	Corda has adopted Blockchain in energy trading by digitizing commodities to reduce process inefficiencies such as low trust and manual documentation practices
Stellar	Decentralized, open-source network for currencies and payments, enabling microtransactions, cross-border payments, and remittances.	• Public • Immutable • Highly scalable • Digital Assets • Lumen Cryptocurrency	• Remittances • Cross-Border payments • Creation of Digital Assets	Stellar-based energy projects leverage the Blockchain technology as a fundraising platform for solar energy projects, a marketplace to buy/sell energy, and to create tokenized carbon credits.
IOTA	It's an open source distributed ledger built for the Internet of Things ecosystem by enabling microtransactions and data integrity for machine-to-machine applications	• Public / permissionless • Feeless • Highly scalable • Low energy consumption of the network • IOTA Token as optional digital asset • Digital identity framework	• Mobility / Automotive • Global trade / Supply Chains • Health • Smart energy • Smart cities • Industrial IoT	The IOTA partner ecosystem is developing a number of use cases, including real time data monitoring from Smart Meters, traceability of energy attributes, M2M micropayment for smart energy assets, Plug & Charge and Green Smart charging and P2P flexibility energy markets

Platform	Objetive	Characteristics	Common uses	Use Case in the Energy Sector
Energy Web Chain	EWF established one of the largest global energy-Blockchain ecosystems and launched the Energy Web Chain, a public Blockchain specifically designed for launching enterprise applications for the Energy Sector.	• Public permissioned Blockchain • Ecosystem development • High throughput capacity • Low cost	• IoT device connection • Green attribute tracking • Electric vehicle charging • Flexibility and grid balancing • Asset and data authentication.	EWF's open-source SDK's, EW Origin and EW Flex, can be applied for building dApps for energy traceability (e.g. Renewable Energy Certificates) and integrating DERs into the grid.

Energy Partnership, 2020

3.4 Definition of Key Principles

Blockchain fundamentals

The emergence of the term Blockchain is derived from the structure of the distributed ledger, which consists of a set of transactions organized and stored inside blocks of information. The blocks are ordered chronologically, and each block is encrypted and assigned its own individual "hash" code; it is then digitally signed by the participant node that validates the block. New transactions[48] pending to be recorded are packed together in a new "block", which becomes the last link in the "chain" of blocks formed by all previous historic transactions. As new blocks are added the chain continues to grow, comprising the distributed ledger that is owned by all network participants.

Key concepts

The Blockchain ecosystem has developed at a rapid pace in recent years, and along with-it new players and key concepts have emerged that are essential to fully understand how this technology can be implemented in the energy industry.

Table 3.2 – Key Blockchain Concepts

Type	Key Concept	Description
Main components within a Blockchain transaction	Hash	A predetermined length code obtained through cryptographic techniques to transform private information. It serves as a mechanism to verify that information encrypted in a block hasn't been altered without the need to actually check it.
	Address	Random sequence of numbers and letters used to receive and send information on the Blockchain, comparable to a bank account, email address or a physical address used when engaging with other individuals through trusted third parties
	Public and private key cryptography	Encryption method that uses two mathematically related keys: a public key to encrypt information and a private to key decrypt it. The latter is uniquely linked to its owner and is used to access information on the Blockchain; it is impossible to derive the private key based on the public key.
	Digital Signature	Used to verify the authenticity of registered information by mathematically validating ownership of certain data on the Blockchain.

48. Allende, M. (2018). Blockchain: Cómo desarrollar confianza en entornos complejos para generar valor de impacto social; Banco Interamericano de Desarrollo; pp. 6.

Clase	Concepto Clave	Descripción
Enabling mechanisms within a Blockchain network	Nodes	Participants of the distributed network that operate and have access to a copy of the ledger. They can engage in multiple activities: issue, verify, authorize, inform etc.
	Mining	Refers to the amount of work required to validate and authorize new transactions within the Blockchain in terms of time, resources and computational power invested to solve a complex mathematical algorithm. Not all Blockchains rely on mining activities to reach network consensus.
	Miners	Participants engaging in mining activities that compete with other nodes to be the first to solve the algorithm, creating new encrypted blocks that contain the most recent information in exchange of incentives/rewards.
	Consensus Mechanism	A method whereby independent nodes authenticate and validate information without the need to rely on a trusted third party or centralized authority.
	Smart Contracts	Smart Contracts are self-execution protocols that take action inside a Blockchain when predetermined enforcement conditions are met.
Key elements within the Blockchain ecosystem	Fork	A significant change in protocol rules or alterations to data on the Blockchain.
	DAO's	Organizations run by a distributed network of participants designed to function in an automated and decentralized way through rules encoded in smart contracts.
	Wallets	Technological tools used to store digital assets owned by a user. There are two types: Hot Wallets are connected to the internet to access funds, while Cold Wallets are physical devices kept offline that can be connected to a computer to retrieve the information.
	Exchange	Serves as a central point for users to buy, sell and trade various types of cryptoassets.
	Payment Methods	External players to the Blockchain ecosystem that offer tools and services to enable and facilitate the use of cryptoassets as a payment method for products and services.

Energy Partnership, 2020

Cryptocurrencies, Tokens & ICO's

Digital transformation is impacting nearly every industry across the world, consequently cryptocurrencies and tokens are becoming more relevant and common assets every day.[49] Some common uses include alternative payment methods, representation of physical assets in a digital world or as project financing tools.

Cryptocurrencies are a digital asset used as a medium of exchange and their main objective is to substitute other functional currencies or to function as a reserve of value. Tokens on the other hand represent a unit of value developed by an organization in order to create an auto governance within their business model, empowering users when interacting with their products or services. There is a vast array of cryptoassets in the market, varying on their uses, functionalities and objectives. Although there is no standard framework for their categorization, table 3.3 shows 7 general types identified:

Table 3.3 – Token Categorization

Token type	Token Description
Native Token / Cryptocurrency	Used as a payment/transaction method within a specific network, platform or services.
Stable Coin / Asset Backed Token	A token type that offers price stability, its value can be pegged to a fiat currency or backed by a reserve asset.

49. Vigna, P., Casey, M. (2015). The Age of Cryptocurrency: How Bitcoin and the Blockchain are challenging the Global Economic Order; Pp. 39

Token type	Token Description
Utility / Application Token	The token is designed to grant access into a specific Blockchain network and to pay for transactions fees.
Security / Revenue Rights Token	Similar to a company stock, this token entitles holders to a portion of fees or profit derived from the network
Infrastructure Token	Allows holders to play an active role in the network maintenance.
Block Creation Rights Token	Token possession determines who secures the Blockchain by turning them into authorized block validators.
Governance Token	Holders have influence over the direction of the Blockchain protocol through voting rights.

Energy Partnership, 2020

There are two token types that stand out for the energy industry. The first case are utility tokens, which entitle users to access certain products or services; identified business models include access to markets such as renewable energies, carbon trading, peer-to-peer energy trading and alternative payment/reward systems. Secondly is the case of security tokens, permitting users to anticipate future profits from the token; this mechanism offers alternative financing models in the form of equity or debt.

High volatility, speculative activities and price uncertainty has discouraged relevant market players to engage in cryptoasset-based business models. Thus, the creation of low volatility digital assets known as Stable Coins has widened possibilities for additional uses with potential for mass adoption. Outstanding cases are Central Bank Digital Currencies (CBDC´s), fiat-currency pegged cryptocurrencies (e.g. Tether) and Asset Backed Tokens (gold, real estate, stocks, etc.). The latter example is highly relevant for the Energy Sector due to their correlation with real-world asset value, such as oil, gas, kWh energy generation, clean energy consumption and green bonds/certificates.

Although cryptocurrencies are a key component to understand Blockchain's current state, ICO's represent a peak hype moment behind the technology throughout the year 2017. ICO's emerged as an alternative financing mechanism to traditional methods like Initial Public Offerings (IPO's) and Venture Capital, promising a more accessible way to raise funds for project development and new business initiatives. Both organizations and investors benefit from this type of mechanisms due to lower entry barriers, lower financing costs, investment democratization and increased efficiency. The following three broad types of ICO's can be identified:

Table 3.4 – Types of ICO

ICO type	ICO description
Utility ICO	Used for the launch of a new cryptoasset which has its own unique feature within a proposed distributed ecosystem. The token allows investors to interact with and utilize the newly created platform.
Equity ICO	Serves as a crowd funding mechanism for a new project by selling equity tokens to investors, which can then be traded on secondary markets.
Debt ICO	Issuance of tokenized corporate bonds and syndicated loans over a Blockchain. Smart contracts enable the automation of the origination, distribution, allocation, execution, confirmation and interest payments of the loan agreement.

Energy Partnership, 2020

The emitted tokens represent the foundations of a proposed Blockchain ecosystem, and they are used as value units for future transactions. The energy industry has identified opportunities leveraging this type of mechanisms for project finance of renewable energy infrastructure, shared investments in the case of external landlord-to-tenant electricity supply[50] and crowdfunding platforms to fund renewable energy projects through tokenization.[51]

However, ICO's have caused skepticism and doubt for Blockchain technology due to frauds, regulation uncertainty and legal constraints. Consumers are exposed to significant risks when engaging in ICO's, some examples are: lack of transparency on how the raised funds are being used, fund raising initiatives launched by inexistent companies, projects not reaching their funding target and overall frauds related to false project initiatives. As a result, users have become skeptical of ICO's and rarely accept them anymore due to transparency concerns and their non-binding funding mechanisms.

As a result, new trends in Blockchain-based funding mechanisms have emerged. Security Token Offerings (STO's) attempt to combine the best of both IPO's and ICO's by offering a transparent and efficient funding mechanism through dividend distribution. They are subject to existing regulations, require external auditing and promote collaboration with financial authorities. Initial Exchange Offerings (IEO's) are second generation ICO's. They restrict fund raising to users from specific crypto-exchanges, who must review and approve participating projects subject to certain criteria, providing greater certainty and transparency to consumers. Lastly, DAICO's seek to merge the main benefits of DAO's and ICO's through DAICO contracts published by a development team raising funds.

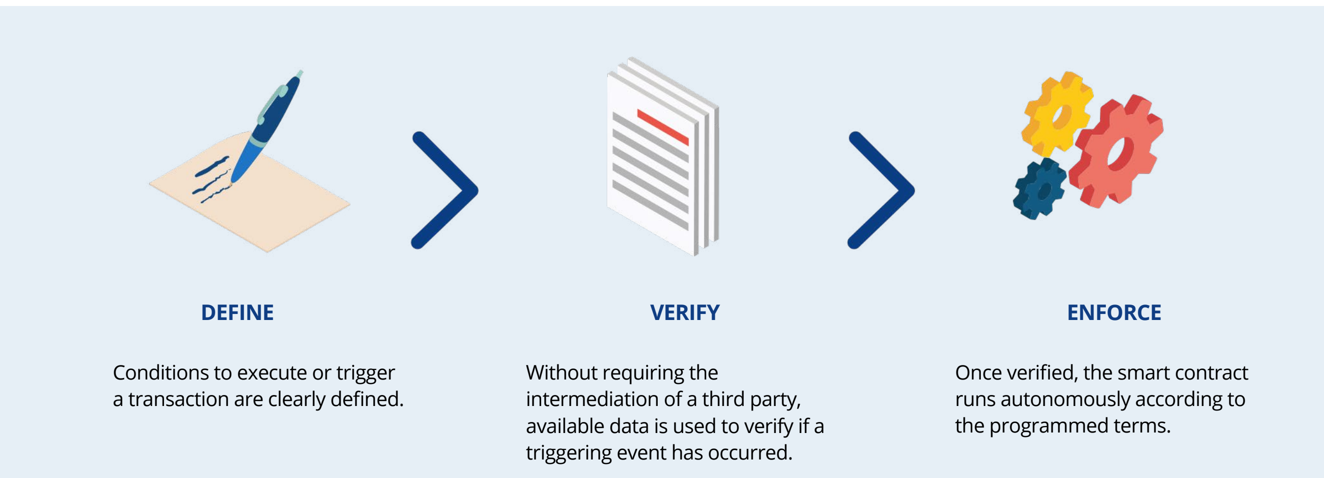
This allows users to contribute ETH to the contract through a preset mechanism, giving them power to vote on resolutions such as defining periodical budgets according to project advancements or shutting down the DAICO to get a proportion of the remaining money back.

Despite the multiple uses and benefits cryptoassets can offer, there are several factors and challenges to have in mind before engaging in new business models revolving around them. Strategic considerations must be well defined and aligned to organizational and business priorities to ensure a valid business and operating model within a structured governance and viable ecosystem, while making sure the proposed solution is technologically feasible. The local context in terms of legal and fiscal aspects, regulatory uncertainty and accounting components may also pose significant challenges when designing a cryptoasset-based strategy.

Smart Contracts

Smart contracts are auto-executable protocols that are encrypted within transactions, leveraging the security, immutability and transparency characteristics of Blockchain. They react to a set of preset conditions or events defined in code, automating a specific process without the need of intervention from parties involved. It's the distributed nature of a Blockchain ecosystem that allows automated processing for transaction management in a secure and immutable way. Smart contracts can be used in multiple scenarios by fulfilling three key steps:

Graph 3.3 – Smart Contract Basic Understanding



Energy Partnership, 2020

50. Richard, P., Mamel, S., Vogel, L. (2019). Blockchain in the integrated energy transition. Deutsche Energie-Agentur GmbH (dena) pg 84.
51. Peter, V., Paredes, J., Rosado, M., Soto, E., Hermosilla, D. (2019). Blockchain meets Energy. German-Mexican Energy Partnership (EP) and Florence School of Regulation (FSR). pg. 45.

The main benefit this functionality offers is risk mitigation derived from delays and third-party dependency involved in manual processes. However smart contracts also present certain limitations, for example, they are highly inflexible since they can´t adapt to a change in circumstances or preferences by the parties involved. Hence, their use should be restricted to consensual relationships in agreements with low dispute probability.

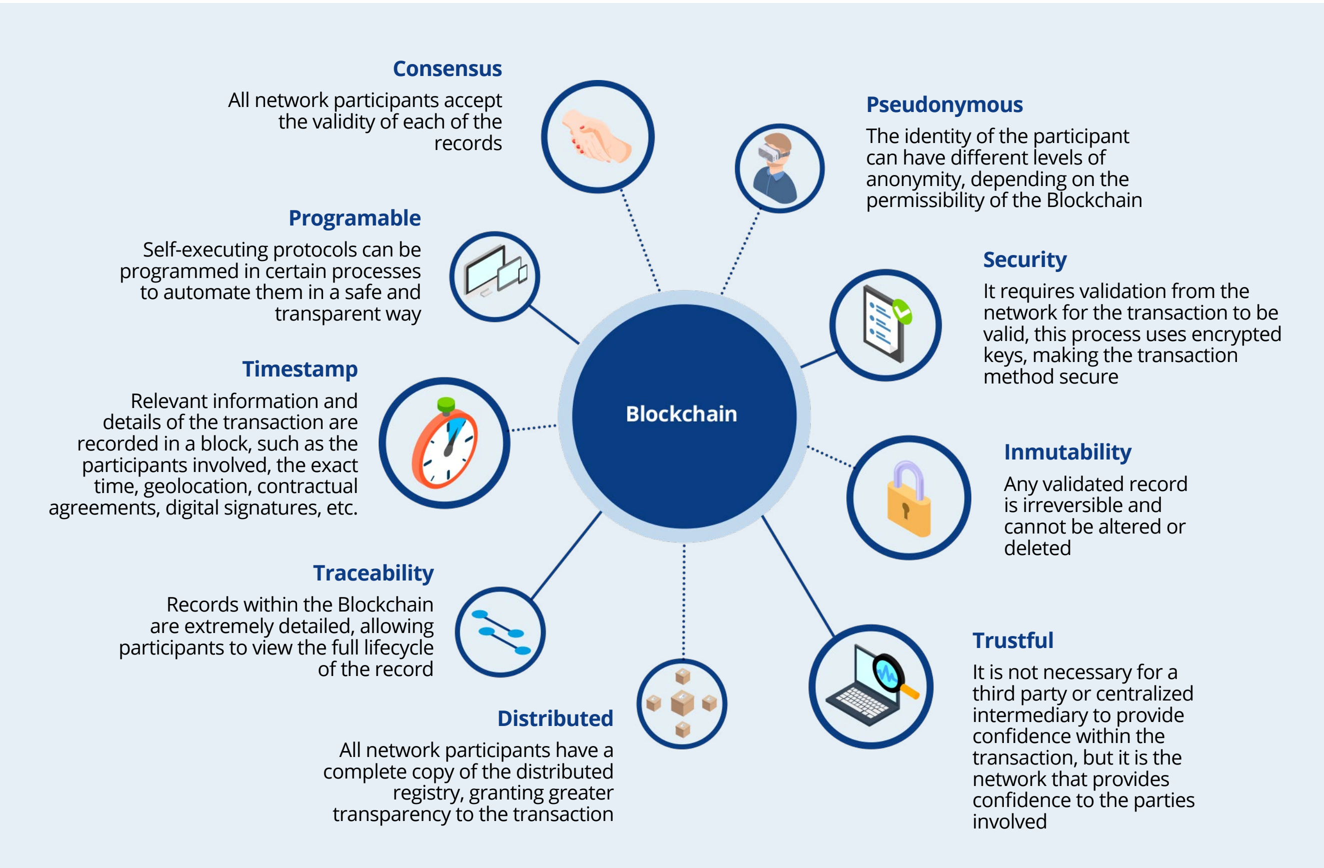
In addition, the defined conditions and events must be predictable and well defined. The code inside the contract is too rigid to allow changes from unforeseen circumstances that would require adjustments.[52] If smart contracts are understood as code, it is reasonable to assume that coding practices contemplate flaws that must be iteratively improved, but Blockchain's immutability makes contractual amendments a difficult task. This in turn raises issues regarding the notion of "once-defined always valid" approach of smart contracts.

A clear example of smart contract applications is through (IoT) technology.[53] Devices connected to the internet are continuously generating valuable data, making them an excellent source of information to be registered in the Blockchain which can be exploited to identify certain predefined conditions in order to detonate events through smart contracts. Potential applications can be found through the use of smart meters, which can be programmed to supply power or cut it off through a prepaid meter business model, grant credits or certificates to energy generation from renewable sources or even enable a microgrid that allows prosumers to engage in peer-to-peer energy trading.

Main benefits and advantages of Blockchain technology

Key Blockchain characteristics shown in Graph 3.4 have triggered interest among industry leaders by offering the possibility to provide safe and efficient transactions while streamlining and automating processes and reducing operational costs. This is why it has become a key disruptive technology to consider when designing digital transformation strategies.

Graph 3.4 – Key Blockchain Characteristics



Energy Partnership, 2020

52. Boucher, P. (2017). How blockchain technology could change our lives; European Parliament Research Service; pp 17.
53. Tapscott, D. & Tapscott, A. (2016). Blockchain Revolution: How the Technology behind Bitcoin is Changing Money. US: Portfolio; pp 102.

Identified benefits include: increased efficiency, cost reduction, process automation, high security, elimination of a single point of failure and diminished record keeping errors. However, the most relevant advantages of Blockchain lay behind its power of driving transparency and trust. Additional direct and indirect benefits identified by William Mougayar are analyzed from the Energy Sector perspective[54]

- Enhanced privacy, protecting sensitive information originated from consumers, organizations and devices connected to the system through permissibility mechanisms.
- Lower risks, loss reductions and cost savings in current processes due to higher data traceability and monitoring, lower data manipulation, reduced human errors and information cohesion.
- Transparency of events and access to trustworthy information by participants with required access levels, leaving a reliable audit trial with a "single source of truth" for compliance requirements.
- Increased productivity and efficiency derived from the automation and digitalization of manual processes that can be programmed within the Blockchain.
- Utility optimization in terms of enhanced revenues and business growth gained from a better customer experience, access to new markets, opening of advanced digital channels and enablement of new business models.

Main Blockchain challenges and obstacles

Pointing out critical challenges the technology is currently facing is equally important in order to achieve its full potential. Key points of focus include current technological constraints, legal concerns, regulatory uncertainty, business transformation and overall perception and understanding of the technology. Mougayar categorized key challenges by impact area,[55] the following analysis will be based on the same approach:

Table 3.5 – Blockchain Challenges

Category	Identified challenges
Technical: Technical feasibility and current development of the technology.	• Scalability in terms of high-volume information processing • Interoperability with existing hardware/software in the industry • Lack of interoperability with other Blockchain protocols • Infrastructure maturity in the market (e.g. smart devices, PV installations, etc.) • Lack of mature industry-specific solutions and developers • Continuous evolution of the technology • Absence of industry standards within the ecosystem
Social / Educational: Social, cultural and behavioral components for industry Blockchain adoption.	• Lack of technology understanding in the market • Skepticism and disillusionment due to technology hype and overpromise • Resistance to welcoming new paradigms in terms of trust and transparency • Change management for both organizations and consumers • Deficient industry-wide executive vision
Legal / Regulatory: Main source of uncertainties and barriers behind Blockchain technology.	• Overall regulatory uncertainty for Blockchain-based business models • Accounting, financial and fiscal regulations applicable to certain use cases • Information/data privacy and cybersecurity concerns • Unclear government role within the industry and future Blockchain ecosystem • Compliance with industry specific norms and regulations
Market / Business: Critical for decision makers in order to explore further into Blockchain initiatives.	• Translation of industry needs into quality ideas and initiatives • Insufficient data to support the success of existing projects and use cases • Market adoption through network effects and initial critical mass • Inadequate business models and governance structures for proposed projects • Market decentralization and user experience prioritization • Lack of qualified human capital for technological development/implementation • Long term business mind set in terms of cost-benefit innovation dilemmas

Energy Partnership, 2020

54. Mougayar, W. (2016). The Business Blockchain: Promise, Practice and Application of the Next Internet Technology;
55. Mougayar, W. (2016). The Business Blockchain: Promise, Practice and Application of the Next Internet Technology;

Other significant challenges identified by Nayam Hanashiro from R3 when designing, developing and implementing Blockchain solutions include calculating an estimated return on investment with limited benchmark information, achieving an executive level comprehension of the technology by decision makers and finding adequate collaboration schemes at an industry level. It is important that industry leaders assess these challenges accordingly before engaging in a Blockchain initiative, as it is more often than not that projects fail due to obstacles encountered in these areas rather than technological maturity or feasibility issues.

Moreover, investments in emerging technologies, implementation processes and the development of new business models unchain several risks. Not identifying them promptly can cause severe damages at an organizational, structural and market level. Some palpable risks for Blockchain application developers, infrastructure providers, organizations, industry consortiums, regulators and governments are:[56]

- Transaction risks that can cause systematic vulnerabilities such as price volatility, rate fluctuations and grid stability.
- Interoperability between platforms, both existing legacy systems and future alternative Blockchain platforms that emerge in the market.
- Sufficient scalability in order to handle high volume transaction levels as the network grows. The grid must be able to carry out volumes comparable to real world scenarios within the energy industry, such as payments, billing, energy generation/consumption, commodity trading, etc.
- Regulatory restrictions or lack of a regulatory framework that provides certainty among investors and consumers considering Blockchain based business models.
- Correct change management for a successful Blockchain implementation from an organizational perspective, as well as market acceptance and adoption from a user point of view.
- Lack of trust in the distributed network in terms of security, data privacy, information integrity, governance, access management and platform maintenance.
- Response capabilities from government and authorities in order to regulate the use of Blockchain in different scenarios such as utilities trading, asset/data management and project finance.
- Redefinition of governance structures due to shifting paradigms from highly centralized models, maintaining relevant roles involving government, regulators and policy makers.
- Reputational risks regarding Blockchain technology and specific protocols in terms of frauds, price volatility, cybersecurity breaches, theft and new business model performance that can harm market perception.

Current challenges and risks are a clear reflection of the technology's current maturity level. Though further development is still required for mass adoption, the Blockchain ecosystem is marked by strong collaboration focused towards developing and improving solutions. Significant advances in the Energy Sector are still underway, led by relevant projects which continue to develop the ecosystem through research and development, pilot execution, Blockchain industry consortiums and experience gained from market available solutions.

3.5 Blockchain Architecture

Blockchain categories

Blockchain technology does not offer a "one size fits all" solution, therefore there are multiple architecture models varying on the main objective and overall purpose of the distributed ledger application. Public Blockchains serve best for a completely open network where information accessibility is equal to all participants, while private Blockchains may have restricted access and permissions assigned according to each participant's accessibility permissions. The following table illustrates the main Blockchain categories to consider:

56. KPMG International. (2016). Missing link: Navigating the disruption risks of Blockchain. Obtained from pp. 5-6.

Table 3.6 – Blockchain Categories

Public Blockchain	Private Blockchain	Consortium Blockchain
Permissionless ledger - anyone can join the network	Permissioned Ledger - only a selected group of organizations can participate	The network is controlled by a group of participants
Completely decentralized environment	Distributed environment among authorized parties	Partially decentralized environment
Consensus using public nodes	Custom consensus engine that uses private nodes	The nodes are preselected
The transactions are public and can be consulted in the historical record	Consensus permissions strictly controlled for transaction validations	Exclusive for a group of organizations, does not allow anyone to participate
The distributed ledger is transparent, showing all validated and non-validated transactions	The distributed ledger is accessible only to permissioned participants	The distributed ledger could be public or arbitrarily restricted
Open to any participant, nodes can be added to the distributed network	Facilitates changes to the Blockchain protocol rules	Allows verification of reliable nodes and the possibility to modify them
Ex. Bitcoin, Ethereum, litecoin, IOTA Tangle	Ex. Hyperledger Fabric, Microsoft Azure, Corda	Ex. B3i, tradelens

Energy Partnership, 2020

Consensus algorithm

An important component of the technology is the consensus algorithm, a mechanism used to authorize and validate transactions conforming the distributed ledger. The concept consensus refers to the outcome of a decision-making process engaged by a group without any conflict from the involved parts. Adopted by informatics and computer sciences, this term is fundamental for distributed ledger technologies.

Blockchain's consensus mechanism is an algorithm, also described as a set of rules, which maintains the ledger entries in a coherent manner across all participating nodes. This is how members of the network agree upon the validation of proposed transactions that must be updated on the distributed ledger without the need of relying on a trusted third party. There are various types of consensus mechanisms that adjust to the protocol's objective, varying on performance, scalability, security, speed, governance and failure redundancy.[57] The following table provides a set of popular consensus mechanisms and protocol examples that use them:

57. KPMG US. (2016). Consensus: Immutable agreement for the Internet of value. New York, US. Obtained From KPMG,; pp. 3

Table 3.7 – Consensus Mechanisms

Type	Description	Example
Proof of Work (PoW)	Validators/miners compete against each other to solve a cryptographical problem through the use of computational power to validate transactions and add a new block in the distributed ledger.	• Bitcoin • Ethereum[58] • Litecoin
Proof of Stake (PoS)	Validator nodes are selected randomly, where the probability of being selected is proportionally related to the wealth of validators. Therefore, block geneartion depends on the stake nodes have invested in the system.	• Neo • Dash
Practical Byzanitine Fault Tolerence (PBFT)	Validator nodes, which are known by the network, are responsible of verifying and validating new transactions, consensus is reached when there is a of sufficient amount of signatures collected. PBFT is a suitable tool for trusted and private environments, as opposed to public distributed ledgers.	• Hyperledger • Zilliqa
Federated Byzantine Agreement (FBA)	Validators/Nodes choose other nodes they trust in the network, which form quorums (set of sufficient nodes to reach an agreement) and quorum slices (subset of nodes in a quorum that can convince one given node about agreement). Transactions are accepted when the majority of nodes on the network are in agreement	• Ripple • Stellar
Proof of Authority (PoA)	Special permission is granted to certain members of the network to generate new blocks, validate transaction and make changes in the blockchain. The network places trust into said authorized nodes, where their own identity is put at stake as an incentive mechanism to maintain the distributed ledger updated and reliable.	• Energy Web Foundation • JPM Coin

Energy Partnership, 2020

Selecting the right consensus mechanism is essential for a meaningful implementation of a Blockchain solution. It will be the most important element behind the network governance, providing participants how the protocol will operate and what the role of nodes will be. The consensus mechanism establishes a decentralized control without the need of a central authority to provide trust among parties by reaching a consensus from a network majority (majority definition is also subject to protocol rules).

Important governance considerations to have in mind when choosing the Blockchain architecture are changes and updates to the network, onboarding and offboarding nodes, managing permissions and accessibility to authorized users. There are several governance models that can adjust to the Blockchain application and intricacy of the proposed use case. In the particular case of the Mexican Energy Sector it seems likely that a private or permissioned Blockchain are the architectures that best align to the industry needs, considering concerns expressed by relevant public sector representatives in terms of governance and accessibility.

Governance can be fully decentralized, leaving network participants to decide whether or not they agree with a certain change through optional software updates, Decentralized Autonomous Organizations (DAO's) or voting mechanisms available to users. Development foundations are another governance structure that support the growth and adoption of a specific Blockchain protocol through strategic decision-making aligned to certain objective. Lastly, an industry consortium governance can be set up to define clear rules and objectives, integrating interests from all participants; consortium governance models are the most appropriate for industry level solutions for the energy industry, due to market complexity and sensibility.

58. Ethereum is currently undergoing an implementation process to change their consensus mechanism from PoW to PoS, scheduled to be completed throughout the year 2020.

3.6 Criteria for Technological Adaptation

Key questions to ask for identifying Blockchain application opportunities

Identifying opportunities for Blockchain adoption is a common challenge for organizations, especially when it comes to translating business pain points into viable solutions. Overpromising expectations behind the technology has resulted in an overwhelming number of use cases attempting to solve issues for which Blockchain is not necessarily the best answer. This is mainly because the technology is widely misunderstood, and therefore suggested as an unfit solution to a wide array of problems.

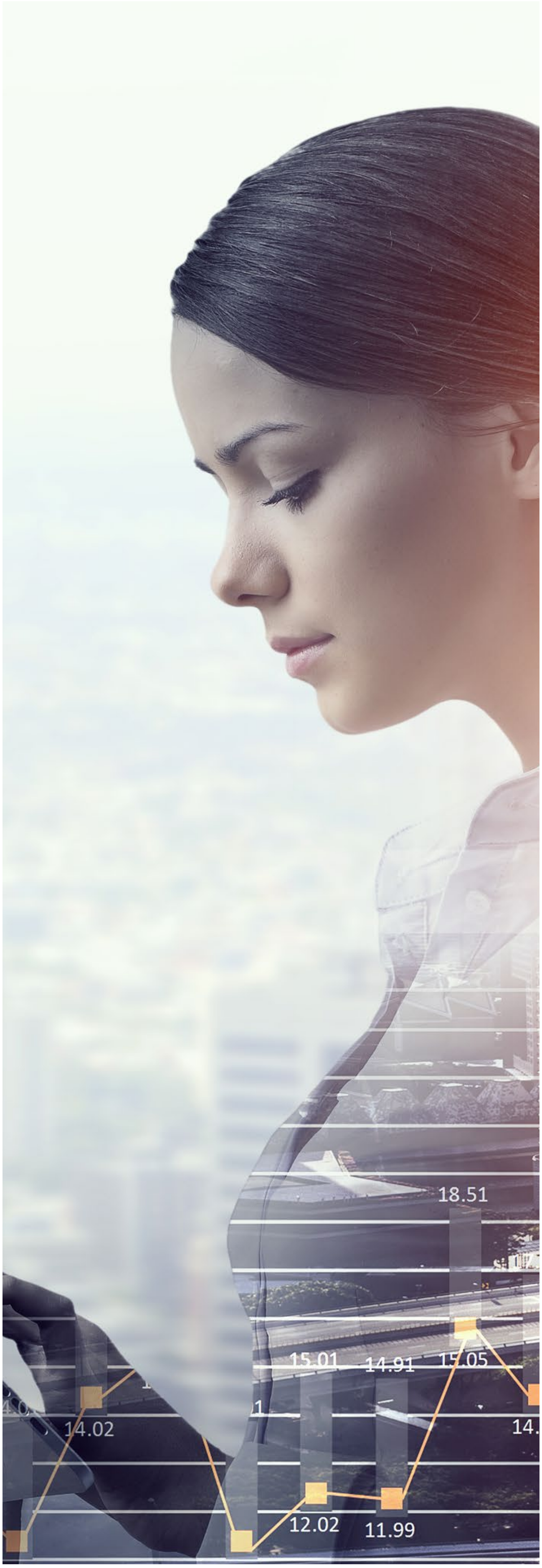
Furthermore, Blockchain does not offer a standardized solution that can be applied equally under different circumstances or fields.[59] Instead, it must be understood as a tool that can be adapted to solve specific pain points for which the technology offers tangible benefits. Each case must be evaluated individually in order to determine if it is suitable for Blockchain adoption. An initial assessment can be achieved by asking the following strategic questions regarding an identified process:

1. **Are multiple parties sharing and replicating data?**

   Blockchain makes most sense when there are multiple participants replicating large amounts of data, otherwise a traditional data base would most likely be a more effective solution. A first step in evaluating a potential Blockchain solution is to identify all parties involved within a process, along with the information they are generating and sharing with other participants. Potential participants in the energy industry might be perceived as consumers, energy generators, regulators or even smart devices or internet-connected hardware that generates relevant information.

2. **Are multiple parties updating the data?**

   The information registered on the Blockchain must be produced continuously and subject to frequent changes (e.g. monetary transactions among individuals). If the selected process consists in a single-time transaction then Blockchain is not a suitable solution, as a key component of the technology is to enable a chronological growing record of information. Such data behavior can be seen in



59. Allende, M. (2018). Blockchain: Cómo desarrollar confianza en entornos complejos para generar valor de impacto social; Banco Interamericano de Desarrollo, pp. 28-30.

energy supply and demand data within an electric grid or in price changes for a certain commodity that is being traded.

3. Is there a lack of trust between the involved parties?

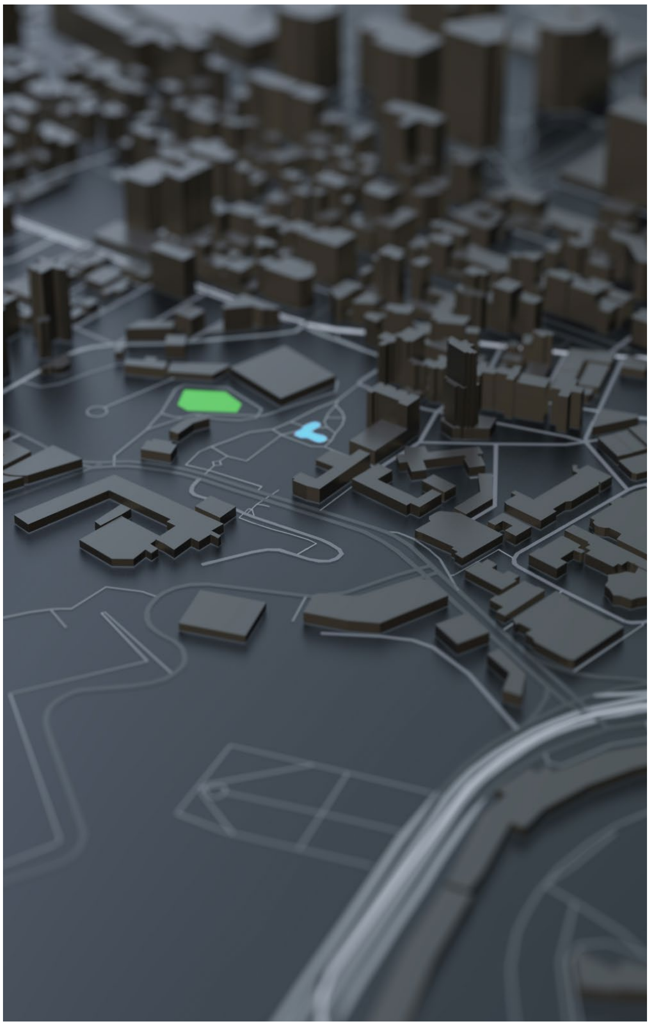
The process requires interaction among parties that suffer from a lack of trust among them. One way to identify this is if intermediaries or third parties are involved in a process as trust providers by validating or authorizing information. The distributed nature behind Blockchain offers an alternative trust mechanism in order to enhance this type of interactions. Some examples of relevant processes include carbon emission trading, contractual agreements between generators and distributors and project finance operations.

4. Are the rules governing all participants' uniform?

Rules defined in the Blockchain protocol must apply equally to all participants. This includes the consensus mechanism used to validate and authorize updates in the ledger, transaction speed, security, block size and governance structure of the network. However, accessibility and permission management for users may vary for transaction visibility and information privacy related concerns. For instance, supply chain solutions for asset management involving hardware equipment and installations must respect uniform governance rules for all involved parties (material providers, assemblers, warehouses, distributors, maintenance suppliers, selling points, etc.), although not all participants will be able to visualize all interactions throughout the supply chain, only those relevant to them.

5. Are the network rules stable?

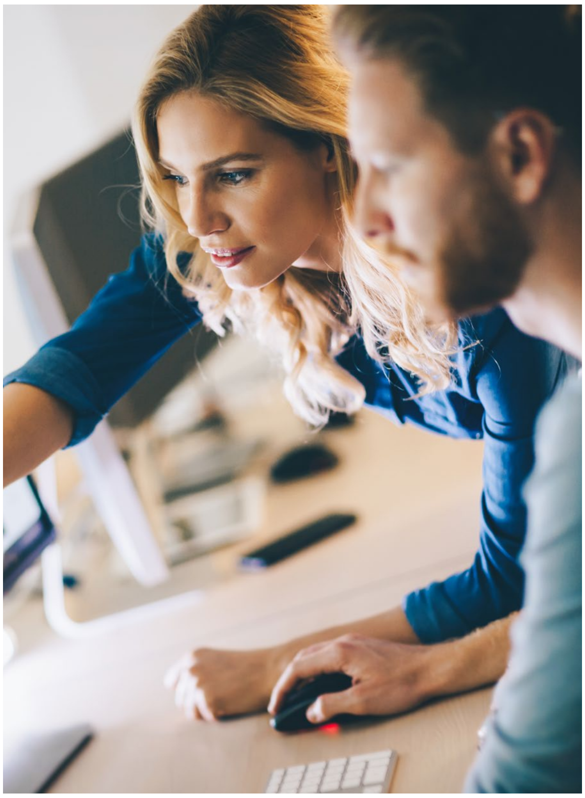
This is a key element since Blockchain is essentially a set of rules that participants accept when joining a network. Change in rules, also known as forks, must be accepted by the majority of network participants; those who do not agree with the proposed changes may opt to abandon the network. Frequent rule changes in the distributed network will cause it to become increasingly fragmented, decreasing the number of participants and thus making Blockchain technology inconvenient. A possible network change could be related to the consensus algorithm, for example switching from a PoW to a PoS mechanism in order to increase transaction scalability and speed in a rapidly growing network.



6. Is objectivity and immutable logging of information required?

Information recorded on the Blockchain cannot be altered or eliminated. Instead, any required modifications must be made by updating the information on the distributed ledger, consequently changes become visible to network participants. Hence Blockchain must only be considered in circumstances where information immutability truly adds value to the process. For example, traceability and monitoring of renewable energy generation and consumption is a compelling case in favor of information objectivity, where immutable records are in the best interest of market stakeholders.

Several Blockchain projects and initiatives have failed when applied in areas where the technology does not offer a solution aligned to the benefits that it offers. The abovementioned criteria can be helpful for a quick evaluation of Blockchain opportunities, both from a developer and a user point of view. Ruling out situations where the technology doesn't make sense is essential to prevent significant investments in solutions that are destined to fail, and more importantly, to identify opportunity areas where Blockchain's full potential can be unlocked.



General Blockchain applications

Another helpful approach to determine when Blockchain is an applicable solution is by thinking of relevant functionalities and scenarios where it can be applied. Don Tapscott identified 8 high potential impact features for the banking industry,[60] however they can also be translated into other industries. Hereunder are examples of said features applied to the Energy Sector:

1. Identity/value authentication:
   Origin certification in the form of carbon footprint credits.

2. Value transfer:
   Transactions involving goods or services, specifically peer-to-peer energy trading.

3. Value Storage:
   Cryptocurrencies or Tokens representing kWh energy generation.

4. Value loan/deposit:
   Green bond markets or prepaid meter schemes.

5. Value exchange:
   Commodity hedging through smart contract-based financial instruments.

6. Financing and investments:
   Token-based project finance mechanisms for infrastructure investments.

7. Value assurance and risk management:
   Asset ownership proof and protection with an audit trail.

8. Value accounting:
   Automated billing and settlements for Power Purchase Agreements.

60. Tapscott, D. & Tapscott, A. (2016). Blockchain Revolution: How the Technology behind Bitcoin is Changing Money. US: Portfolio.; pp 64.

The role of consortiums

Blockchain's intrinsic nature is to develop distributed ecosystems, acting as a catalyst for industry collaboration to solve common pains (e.g. frauds, theft, transparency, information asymmetries, compliance, reporting, etc.) while maintaining healthy competition. A Blockchain-based platform offers an efficient and reliable solution for bilateral communication and information exchange among relevant players, including: organizations, regulators, government authorities, supervisory bodies, international entities, associations, among others.

There are several considerations to address when designing an industry Blockchain consortium. First, all parties involved must define the governance in terms of legal and organizational structure, roles and responsibilities, risk management, regulatory compliance and future entry and exit of network participants. Secondly, financial ambitions must be set: revenues, investments, margins, and the underlying economic model of the solution.

Afterwards comes the business model design, including target markets, value chain focus, channels, products and services; a business case must be developed so stakeholders can assess the consortium feasibility. Lastly the operative model must define the technology and infrastructure used, core business processes, people and culture, measures/indicators and incentives that will revolve around the proposed solution. The following table depicts the main industry pain points and benefits associated to Blockchain consortium initiatives:

Table 3.8 - Industry Pain Points & Blockchain Consortium Benefits

Industry wide pain points	Key benefits
Inefficient data reconciliations between engaging parties	Single source of truth for all parties involved, avoiding reconciliation mismatches
Delayed/insufficient access to data due to paper-based audit trails	Real-time data accessibility for transactions or interactions occurring among participants
Limited insight in industry participants' internal control processes	Enhanced insights into industry participants' controls and processes
Industry participants need to comply with different requirements	Cost reduction for all parties involved
Double administration efforts resulting from inefficient processes	Enforces standardization across all parties involved
Regulator has limited access to relevant data from industry participants	Enables active regulatory supervision from relevant industry authorities

Energy Partnership, 2020

A successful industry consortium initiative for a Blockchain solution is strongly linked to the presence of clear leadership. Organizing relevant players towards a shared goal is a complex task that requires a leader that can support all participants while establishing a specific agenda for the Blockchain proposition and use case assessment.

Additionally, involving regulators and working closely with them towards developing a viable solution and industry standards in favor of all participants is of high value when building the consortium. In an interview, Nicolò Rossetto from the Florence School of Regulation, confirmed that it is important to develop stronger coordination mechanisms in an increasingly more decentralized energy system. Due to decentralization, the system has an added layer of complexity, in which it is necessary to coordinate a higher number of players. An industry Blockchain consortium is a first step to achieve this.

Leadership will most likely be defined jointly by consortium participants, this role will not necessarily be assumed by a key industry player (e.g. producers, service providers, operators, regulators, government). It can also be assumed by an external player familiar with both the energy industry and Blockchain technology for full support throughout all critical components involved during the consortium implementation. Ultimately, clear leadership must be oriented towards coordination for developing a solution that provides industry wide benefits among all stakeholders.


0101010001001
100 00 010100
01 101000 001
100 00 010100
100 00 010100
0101010001001

4. Blockchain in the Energy Sector

4.1 Main actors and their roles

For Blockchain to be implemented in the Mexican Energy Sector, players and stakeholders within the market must be aware of its benefits in order to show interest and act towards the digitalization of the sector, as well as to create new business and operative models, both enabled through this technology. An important factor to consider is that collaboration is of utmost importance for Blockchain implementation, which means private, public and non-government organizations must work together and synchronized. As mentioned by Ole Langniss, CEO at OLI Systems GmbH, collaboration is needed between the new and the old industry; there is not a single company with the solution, which means various companies must work together and contribute through their expertise and resources towards a common goal. Experts also mentioned that collaboration is needed within a company, IT teams should not be the only ones involved in adapting Blockchain solutions, education and communication is needed across the entire company.

Usually, the public sector defines the regulatory framework that allows the private sector to explore the technology and create Blockchain enabled solutions, while NGOs or associations support the process. However, collaboration is also important from a cross-sector perspective. In this case, tech-companies must support energy companies with the technical and technological perspectives of Blockchain solutions in order to enable feasible solutions to create benefits across the energy value chain.

Therefore, the public sector plays a key role to unlock the potential of Blockchain, since it is in charge of establishing the regulatory framework which may boost or discourage the adoption of this technology. They create public policies and establish incentives that could promote or delay the adoption of Blockchain. On the other hand, the private sector drives innovation to discover new applications of the technology and invests in the development of Blockchain solutions.

The mentioned collaboration scheme could vary from one country to another, depending on how the sector is organized and regulated. The key roles of players and stakeholders for Mexico are described below. It's relevant to point out that this is directional and circumstantial, being subject to change over time according to the evolution of the sector.

In Mexico, when considering the creation of a regulatory framework for Blockchain from a cross-industry perspective, a legislative process must be conducted, in which several public entities have a key role. During this process, the Federal Government presents initiatives, promulgates and publishes laws and decrees; and federal deputies and senators participate in presenting initiatives and, when appropriate, approving the corresponding laws and decrees. It was repeatedly mentioned throughout expert interviews that regulatory sandboxes could allow companies to innovate freely, by testing new business models and technologies without regulatory barriers, helping regulators explore and identify adequate regulations for the proposed business model.

From an energy perspective, SENER is in charge of defining the country's energy policy and promoting research regarding new technologies. Nevertheless, apart from the promotion of research, SENER might not be highly involved in establishing a regulatory framework for the use of Blockchain, unless this technology shows the need for a particular regulation specific to the Energy Sector.

For a deep understanding of Blockchain technology, and thus unlocking its potential, it is necessary to invest in R&D. The entity that is in charge of R&D in Mexico is the National Council for Science and Technology (CONACYT), a public and decentralized organization that aims to be the advisory entity of the Federal Executive Power who is responsible of promoting the development of scientific research, technological development and innovation in order to foster the technological modernization of the country. Academics play a fundamental role to generate and spread knowledge that facilitates the integration of technologies into the sector as well. Karla Cedano, from the Renewable Energy Institute at UNAM, mentioned there is an issue with Mexico's talent approach. There is a lot of talent in Mexico for the development of a digital energy system, but it is not integrated. Everyone acts independently, thus slowing down the digitalization progress in the local market. Academia must aid to integrate these efforts as well as to continue developing talent.

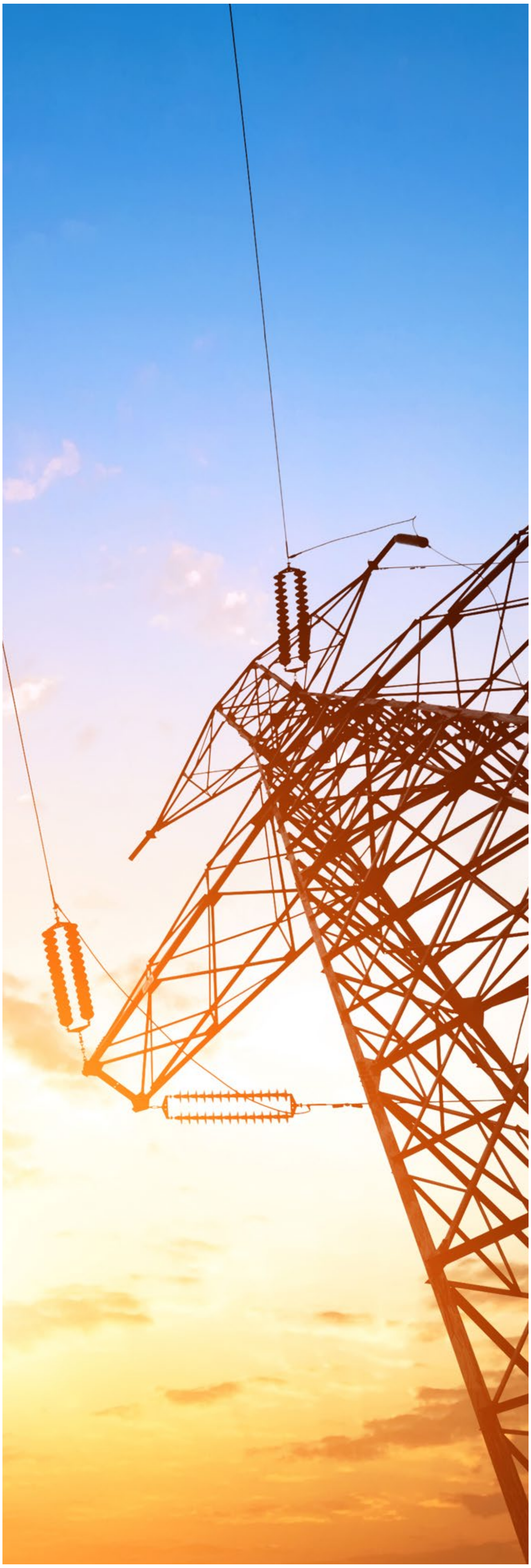
Development banks such as Bancomext or Nafin could be involved through the financing of Blockchain and digitalization projects. Their objective is to contribute to the economic development of the country by boosting innovation, improving productivity and creating jobs. Currently, development banks have active roles in financing and granting credits to energy generation projects at low interest rates, these banks could start to finance and support digitalization and technological projects which could contribute to job generation and improve competitiveness in the market.

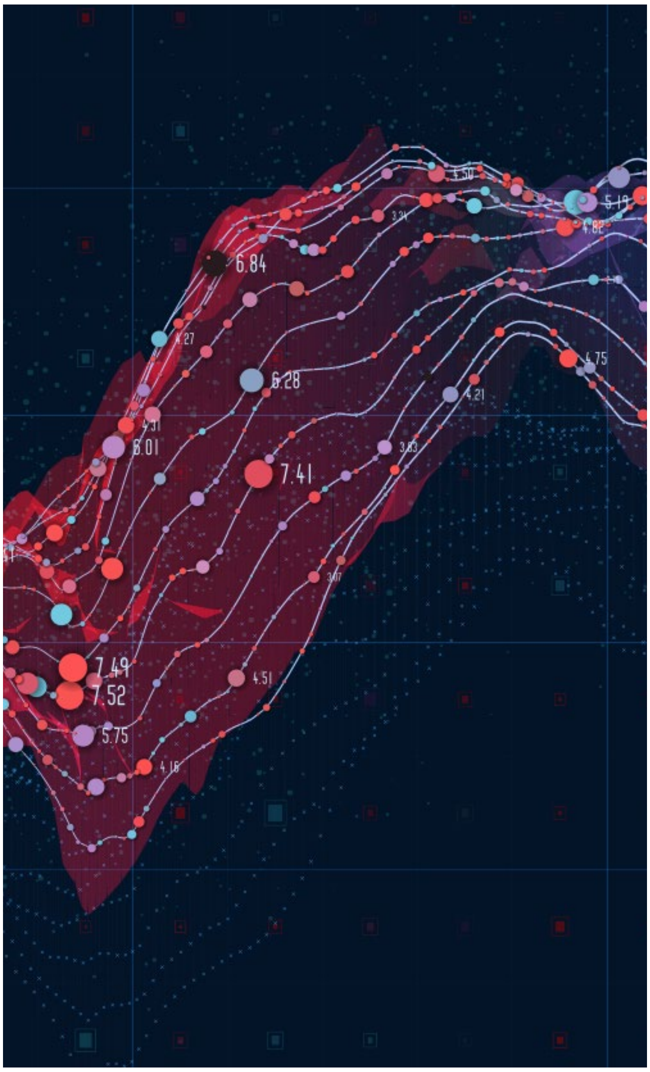
Associations and Non-Governmental Organizations (NGOs) create and boost a collaboration approach across the different participants in the market to identify and constantly communicate the main concerns of the sector. They establish priorities and focus areas within the sector and serve as a bridge between the public sector and private organizations. Foundations on another hand are non-lucrative organizations with a specific objective that usually benefits a community or a sector. One example could be the Energy Web Foundation, which builds core infrastructure and solutions for energy traceability and grid flexibility, speeding adoption of commercial solutions, and fostering a community of practice.

CENACE is also a clear key player as it is in charge of the Wholesale Electricity Market, in which there is a high-volume transaction amount and Blockchain could enable multiple benefits across its value chain. As an independent organization, the operator could apply Blockchain to their everyday operations in order to improve transparency regarding transactions within the Wholesale Electricity Market and/or to enhance monitoring and control in the electricity generation to satisfy the demand.

CFE could find Blockchain useful for its operations as well, since it's the company in charge of transmission and distribution, in which transparency among transactions within the market is highly relevant. For example, it is required to know, for every consumption point, if power was provided by basic supply or if it was bought from a private generator to determine who should be compensated. As the main provider in the country, it also must do a considerable number of billing and netting which could be optimized through Blockchain.

On the other side, the private sector has an important role in the adoption of digital technologies such as Blockchain. The public regulatory entities are in charge of creating a framework that fosters the use of Blockchain, but most of the investment will likely come from the private sector. Kira Potowski commented that the private sector will have a primary role in the energy digitalization, bearing in mind that they are the ones responsible to demand cooperation from the public sector to allow innovation.





Large energy companies seek to implement Blockchain in their business and operative models to take advantage of its benefits. These companies have the advantage of having considerable monetary and human resources to invest in Blockchain implementation, nevertheless they are less flexible to transform their business model completely. On the other hand, startups are coming up with new business models enabled by Blockchain, having more flexibility and making it easier for them to adapt or change their business model.

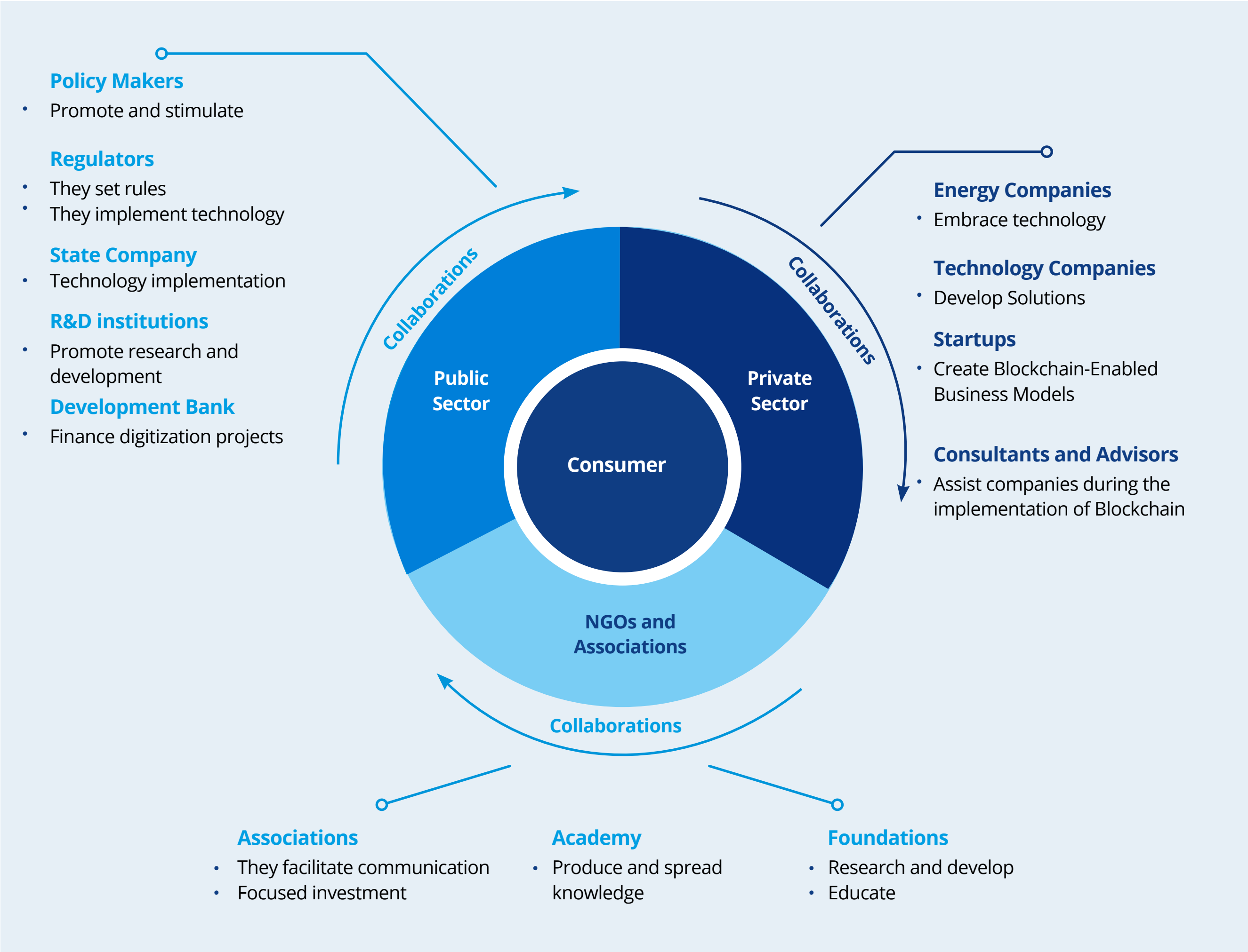
Technological companies explore the uses of Blockchain as a cross sector solution, by investing time and resources in creating business offerings such as asset management or transaction services. Energy related companies can leverage this previous research, or develop new knowledge, to adapt it into the Energy Sector with services such as energy attribute certificates. We might even see alliances between technological firms and energy companies working towards finding the ideal Blockchain solutions for the Energy Sector.

DAOs are organizations that don't have an individual or centralized institution operating them. They use an interconnected web of smart contracts to automate most of their essential and non-essential processes. The role of a DAO is to generate decentralized ecosystems through business models and applications based on Blockchain technology. Bitcoin's PoW is one example, where governance is decentralized among miners through incentive mechanisms. It can also be the case that a public Blockchain protocol has a development foundation which oversees carrying out technical and commercial activities connected to the development of a certain Blockchain ecosystem to achieve predefined targets and goals. Industry experts and external consultants assist the digitalization of the Energy Sector by providing knowledge and experience from specialists in areas such as: energy, digital transformation or specific digital technologies like Blockchain. They could aid Blockchain adoption by generating knowledge, evaluating projects, assuring compliance with industry regulations and standards, creating strategies and assisting during the implementation of the technology.

Another stakeholder, sometimes not considered but with a relevant role in Blockchain adoption, is the consumer. The community must have an understanding of the benefits of Blockchain and trust the technology for them to use it, because even if the private companies adopt Blockchain and offer Blockchain solutions, the community won't demand these services until they understand the benefits and advantages Blockchain can offer to them. In an interview, Jose Miguel Bejarano from Siemens Energy stated that if energy companies implement new technologies such as Blockchain, consumers will benefit in two ways. First, by digitalizing the company's operations, production costs will decrease and the price for generating 1MWh will also decrease, which will transfer to the consumer's electricity bill (mainly qualified users). Secondly, it will provide greater reliability and transparency to access and understand prices and tariffs.

In conclusion, multiple coordinated efforts must be done in order to discover and unlock the full potential of Blockchain. It is not an isolated responsibility as it requires the awareness and commitment from each stakeholder. The following chart presents relevant players and their potential roles across the Mexican Energy Sector.

Graph 4.1 – Main Actors and their Roles



Energy Partnership, 2020

Another important factor that could drive the use of Blockchain in the Mexican Energy Sector is the international landscape in terms of technological developments, business model identification and ecosystem maturity.

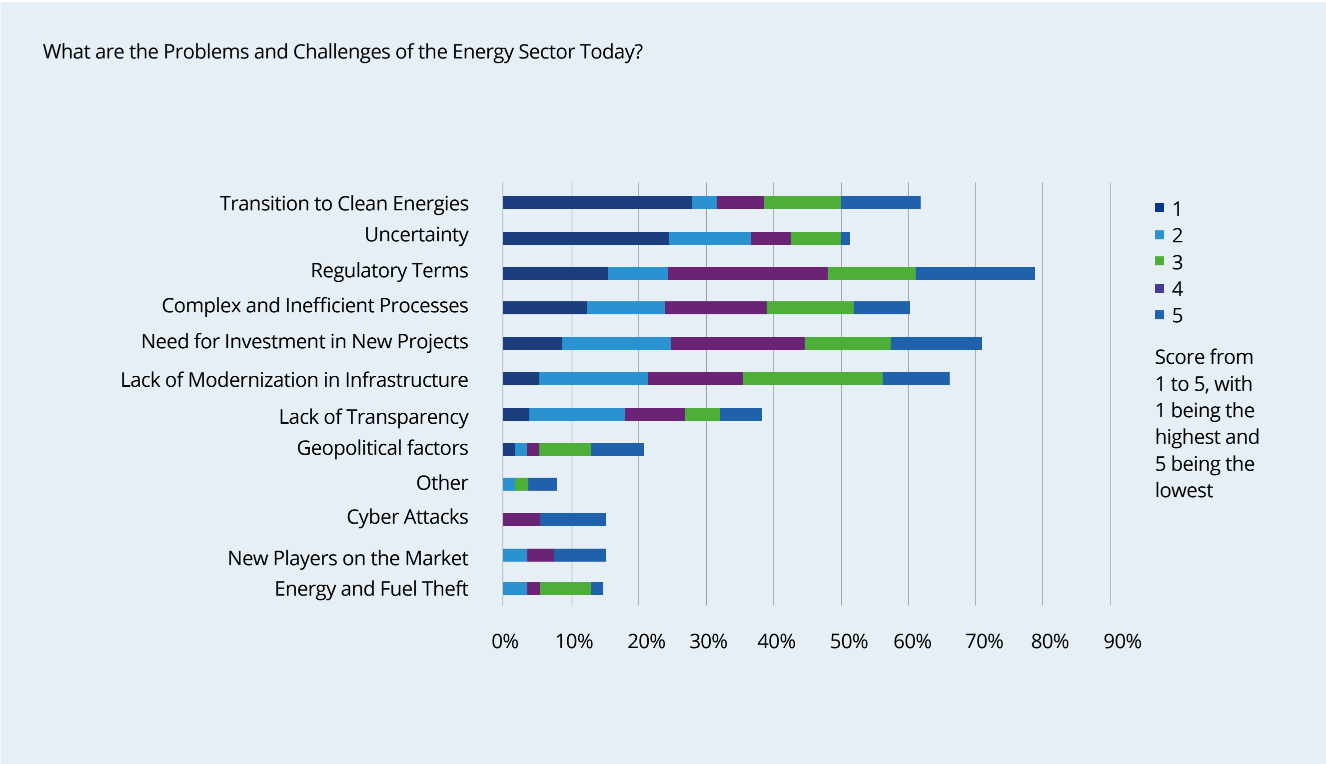
Since there are countries that have already shown considerable progress in Blockchain matter, is it likely that other countries, such as Mexico, try to replicate best practices around the world. This approach requires a proper adaptation adjusted to the local context, considering regulatory, economic, infrastructure and political factors.

Most international energy companies are already testing projects in developed countries to evaluate this technology in the market. Even though energy companies have started implementing Blockchain in some developed countries like Germany, Spain and the United States, Mexico is starting to see some Blockchain solutions being developed in other sectors by companies such as IBM with use cases for insurance and supply chain and Lumit for digital contracts and electronic signatures. Francis Perez, CEO of Ramadasa, pointed out that local energy companies will have to compete with international organizations which are more advanced in digitalization, since they have taken advantage of their scale economies. This allows them to work on their own developments and solutions without the need to depend on a third party. Hence, Mexican companies will face the challenge of keeping up with digitalization trends while maintaining themselves competitive with international players.

4.2 Challenges and opportunities for the sector

Throughout this section, the Energy Sector landscape in Mexico will be analyzed to identify its current pain points and challenges to find opportunities and benefits that digitalization could bring to the industry. To obtain a better understanding of the energy's sector general perspective in this matter, a series of surveys and individual interviews have been held with industry experts. They were asked to select the 5 most relevant challenges and problems in the Energy Sector from the options provided and rate the selected ones on a scale from 1 to 5, 1 being the most relevant and 5 the least. The obtained results are shown below:

Graph 4.2 - Current Challenges of the Energy Sector



Energy Partnership, 2020

The challenge that was considered to be the most critical by participants of the consulted group of experts is transition to clean energy. This represents an important obstacle as it has an effect across the entire value chain. It requires significant changes in the technologies currently used for generation, increases the complexity of the transmission and distribution networks and can generate added value in energy trading.

For generators there has been a lot of progress regarding transition to clean energy, advancements in energy efficiency, as well as in cost reductions in renewable energy equipment have facilitated more investments and made it more profitable. These advancements are making distributed generation grow at exponential rates, which is one of the main challenges of the transition to clean energy. The growing number of prosumers represent a vast amount of transactions and data that has to be tracked and analyzed in real time. A highly digitalized and efficient market operator is required, with access to technological platforms capable of providing transparency, certainty and trust to the market. Blockchain could be one of the tools used to access and monitor all this information in an efficient way, as well as to store it in an immutable and secure way.

The next big challenge regarding clean Energy Transition is the management of distributed energy resources, as well as the complexity clean energy is bringing to the power grid. Meerim Ruslanova, from Energy Web Foundation, points out that the rapid decentralization, decarbonization and growing complexity of the Energy Sector put a strain on its current IT infrastructure. For example, renewable energy tracking systems in legacy markets such as the EU and the USA have been functioning well for over two decades. But today, tracking systems face challenges as the underlying digital solutions are outdated, in siloes and not well fitted to accommodate an ever increasing number of devices and actors.

The solution for this challenge might be technological. The modernization from a traditional power grid to a smart grid is essential to provide secure supply and resiliency. The use of technologies such as batteries, IoT sensors, smart meters, artificial intelligence and the modernization of the grid are key for an effective power grid with a high mix of clean energy. This means that a smooth transition to a sector with a high mix of clean energy requires investments in the modernization of the current infrastructure, which was the third most mentioned challenges from the survey. Until we have a digitalized sector and storage batteries have been developed, fossil fuels and flexible generation such as hydropower will help provide the grid with resilience. As Emma Díaz Ruiz mentioned, fossil energy can serve as a pivot to stabilize the grid and meet demand at grid peak points. Another option to create resiliency for the grid is to connect the national grid with other countries for exporting surpluses and importing when needed, just as a flexible generation system.

The next couple of factors considered as relevant issues are uncertainty and regulatory terms. This means that experts do not have a clear vision of where the market is headed and what regulatory framework will be governing the industry in the near future. As it is a highly regulated sector, market participants heavily rely on this element, therefore a clear definition of the regulatory framework is key for the development of the industry. A lack of certainty regarding electricity regulations for example, can make financial planning difficult, including cash flow forecasting. Regulatory terms also refer to the complex and bureaucratic processes for certain activities in the energy value chain. An area of opportunity in the sector, according to Pablo Anzorena, is to automate certain procedures with the government where requested information can be systematized through coherent data that allows for online procedures to be carried out more efficiently, permitting authorities to verify and authorize most of the information and requirements within these processes.

The factors mentioned above, also refer to uncertainty regarding regulations that can foster Blockchain adoption in the sector. Consulted experts were asked if current regulatory frameworks in their countries enhance the digitalization of the sector, where 17% strongly agree and 22% agree with this statement, while another 9% strongly disagree and 52% disagree. In the case of the Mexican market the use of virtual assets such as cryptocurrencies is the only Blockchain application currently included in the Mexican regulatory framework.

The first Blockchain-related regulatory approach in Mexico, regarding Fintech, Open banking and Virtual Assets materializes in the law that regulates Financial Technology Institutions, better known as the Fintech Law, which came into force in 2018, and was emitted by the National Banking and Securities Commission (CNBV). This regulation establishes the basics regarding the authorized use of virtual assets and cryptocurrencies and states that Financial Technology Institutions are only allowed to operate with a determined virtual asset portfolio previously determined and explicitly authorized by Banxico, Mexico's Central Bank with prior authorization.

In March 2019, Banxico published circular 4/2019 with general provisions related to virtual assets, which states that both Credit Institutions and Financial Technology Institutions, authorized to operate with this asset type, may only do so in internal transactions and must implement controls to avoid transferring the risks they pose to final customers and users. This set of regulations regarding operations with virtual assets (BANXICO, 2019) establish the following general rules for Institutions that intend to operate virtual assets:

- Virtual assets can only by transacted in internal operations and direct or indirect risk transfer to customers must be mitigated.
- Virtual asset exchange, transmission or custody services contracted directly with customers is prohibited.
- Characteristics of authorized assets are determined in detail in relation to underlying asset value, emission controls and protocols, mainly for avoiding volatility, replicas and concomitant use.
- Banxico, as part of the financial innovation group constituted of federal organisms responsible for overseeing the fintech law, is the body responsible for authorization for virtual asset operations, upon presentation by the institutions of a dossier requesting authorization.
- Such authorization request dossier must include business model, benefits and operational manuals that describe mechanisms in which virtual assets are transacted, a comparative matrix with explicit explanation of how regulation will be satisfied, protocols, market, controls and involved personnel roles and responsibilities, risk assessment and mitigation policies and procedures, among others.

The next factor that experts consider a challenge refers to complex and inefficient processes. As mentioned beforehand, there are complex processes within the Energy Sector that include validations, verifications, compensations, conciliations and other labor intensive processes across the value chain. There are several studies, requirements and approvals needed for almost every action in the sector, which typically involves sending and receiving information between different actors, including verifications to identify errors and later correcting them.

Many of these processes could be digitalized to offer a transparent and efficient solution, offering tangible benefits for market players by simplifying and streamlining complex processes which could be considered a pain point in the sector. Relevant actors would upload information to a platform where authorities could verify it in near-real time periods, providing transparency and traceability to all participants involved.

A Blockchain-based solution could further enhance such platform, since all parties involved will have access to the same information (single source of truth), hence optimizing response time for verification and validation processes. This will also benefit authorities by providing a bilateral communication channel with market players that will enable them to virtually review requirements and compliance in real time, saving costs and time. Likewise, industry participants will find it easier to comply with regulations through the use of digital solutions that enhance coordination, tracking, and reconciliation-related processes between public and private sectors, improving communication regarding new regulations emitted and reducing pain points across the market (Douglas Miller, Market Development at Energy Web Foundation, personal communication, April, 2020).

Experts were also asked about the main opportunities regarding digitalization of the Energy Sector. Producing and managing data is consistently considered as an opportunity for the sector. As it is known, data is becoming more valuable over time, since it can offer efficiency, better decision-making, cost reduction and quicker response to changes if exploited correctly. José Aparicio, CEO of Siemens Energy Mexico, stated in an interview that it is important to have a clear understanding of how the available data can be used to create value, as well as to optimize the use of information when implementing digital technologies (cloud computing and data analytics). If distributed infrastructure is developed without the ability to access and understand the available information grid risks will have a considerable increase.

In this sense, Data and Analytics (D&A) can provide solutions across the energy value chain. One example is related to the use of data to enable preventative maintenance to equipment and infrastructure. With the use of data, a generator can know when the plant or the equipment will need maintenance according to its usual performance and certain key performance indicators (KPIs). Gerónimo Martinez stated that preventative maintenance has multiple benefits such as: Data-based decisions, informed investments, remote control of assets and operative certainty.

A key opportunity mentioned by multiple experts in the electricity sector refers to the transmission and distribution grid. Much of the transmission and distribution infrastructure is considered to not be ready for the increasing demand, dynamism and complexity the electric sector is facing. There are several nodes that are highly congested, specifically in the northwest and peninsular regions where the demand has already surpassed the capacity, increasing energy prices by 25% (CIEP, 2019).[61] Several experts agreed that transmission and distribution lines should be a priority regarding investments in the electricity's infrastructure since a congested grid compromises its reliability and safety.

61. Limón, A. (2019). Diagnóstico de costos de congestión en la Red Nacional de Transmisión. Mexico City, Mexico. Obtained from CIEP web page: https://ciep.mx/diagnostico-de-costos-de-congestion-en-la-red-nacional-de-transmision/

Rubén Cruz, head of energy in KPMG Mexico, mentioned that there is an opportunity to improve the monitoring of data in the transmission and distribution grid, by having precise and real time consumption information in order to distinguish technical from non-technical losses and identify where the non-technical losses are located. In Mexico there are considerable losses in the grid, in order to implement a strategy to decrease these losses it's important to identify where the energy leaks are. This is another example of the benefits of gathering and analyzing data across the system.

As mentioned in this chapter there are various challenges that the Energy Sector needs to overcome, nevertheless as new challenges emerge, so do new technologies that provide new functionalities and benefits to the sector. It's important to understand these challenges as well as new technological trends to identify where technology can be a solution.

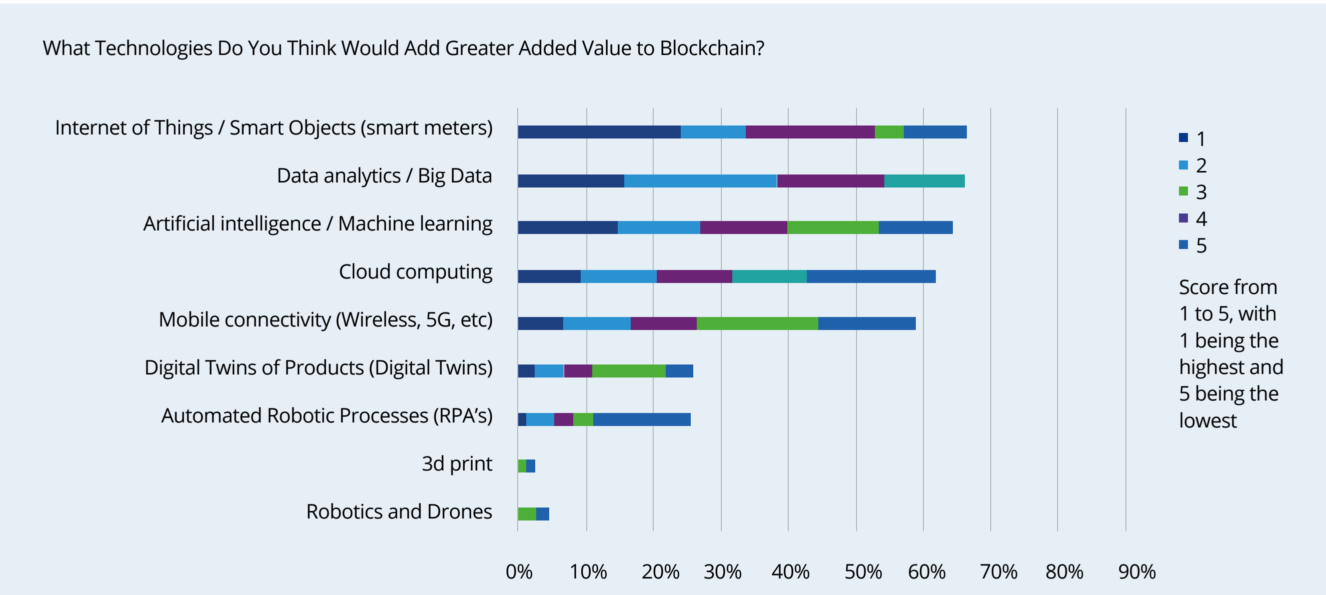
4.3 Additional technologies to consider

The adoption of new technologies has enhanced the Energy Sector regarding its safety, productivity and cost reductions. Digital technologies are widely available, and their costs have fallen dramatically in recent years, particularly for sensors and supporting software, leading to an increase in penetration within the sector.

Technologies are likely to maximize their potential when they work and interact with each other, which applies just as well to the case of Blockchain and other digital technologies. The full potential of Blockchain is achieved when it is integrated into a comprehensive system and interacts with other technologies. Being an information platform, Blockchain needs other technologies to generate, automate and/or analyze the data contained in the distributed ledger, nevertheless, it is important to mention that most functional systems still require human interaction.

In the survey conducted, we asked experts which technologies they believe add greater value to Blockchain, the results are presented below:

Graph 4.3 – Added Value Technologies for Blockchain



Energy Partnership, 2020

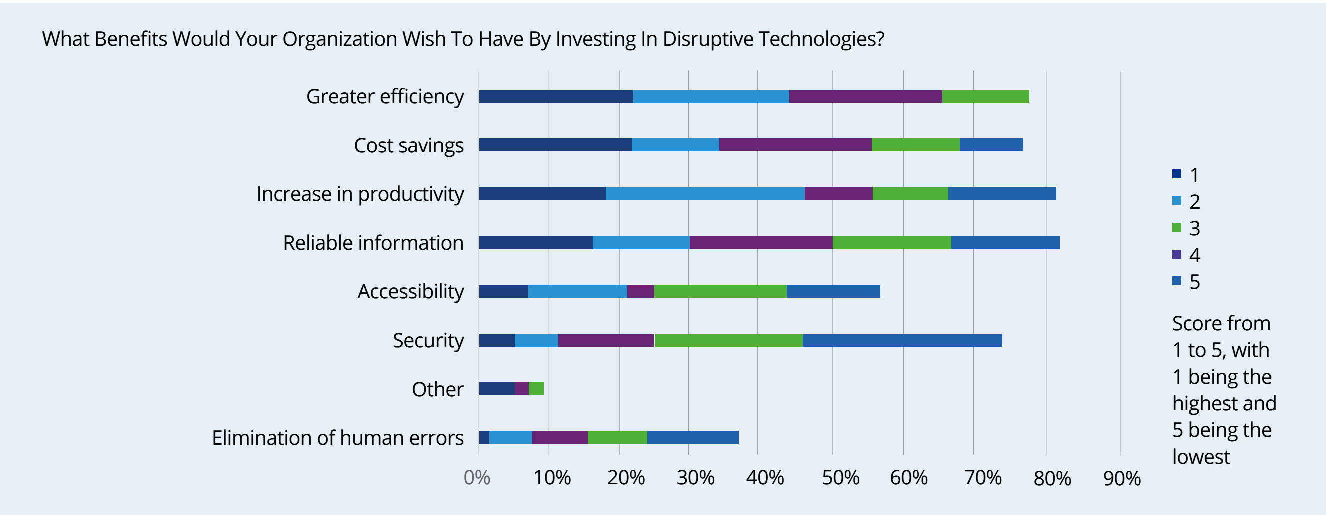
Coincidentally, the technologies that were identified as the ones that will help aid the Energy Sector overcome its challenges in graph 2.7 are the same technologies that experts selected as the ones that add the greatest value to Blockchain. In both cases, the top 3 mentioned technologies were IoT, AI and Big Data. Arturo Duhart, CEO of Sunwise, stated that AI and IoT lead to automation, while Blockchain gives users more freedom in the way we use and access information. Both are technologies that complement each other and offer great benefits when working together. The important thing is to renew the infrastructure and the current system since an old system will not be able to adopt new technologies successfully. This means that there is clear potential about Blockchain creating synergies with these technologies to offer holistic and integrated solutions to help public and private organizations improve their performance and become more profitable, while at the same time creating a more efficient and trustworthy electricity sector.

4.4 Emerging Blockchain business models in the Energy Sector

The development of new business models leveraging digital technologies, as well as the transformation of existing ones, is commonly referred to as digitalization, which in turn represents one of the three main trends in the energy industry. 61% of industry experts expressed the relevance of digitalization in their organization as critical, while 28% consider it to be important, 9% as relevant (but not a strategic priority) and the remaining 2% as not relevant at all. Sean Ratka, Associate Programme Officer at IRENA has pointed out that DLT is not a disruption in the Energy Sector, but rather a solution to disruption caused by the increasing amounts of data being introduced to the sector. DLT, in coordination with IoT and AI, is a powerful tool to help manage and analyze the large amounts of complex data to increase system efficiency.[62]

In light of digitalization's relevance for the Energy Sector it becomes important to understand why the industry is evaluating new technologies as strategic investments in their digital transformation processes. The top driver identified is to achieve greater efficiency, selected as one of the top 5 expected benefits from investing in new technologies by 84% of consulted experts, and as the most important benefit of all by 22%. Other relevant benefits selected by respondents include: access to reliable information (81.5%), to increase productivity (81%), cost savings (76.5%) and enhanced security (64%). Other benefits mentioned by experts include reliability and security of the products/services they offer and entry to new markets, products and services.

Graph 4.4 – Benefits from Investing in New Technologies



Energy Partnership, 2020

Digital technologies are often perceived as tools that provide greater efficiency and increase productivity, in both cases through automation, process digitalization, cost reductions and an enhanced access to data. Some mature technologies available in the market that offer these benefits are Enterprise Resource Planning solutions (ERP's), Robotic Process Automation (RPA's) and Cloud Computing, while other emerging technologies such as AI, Machine Learning, Big Data, Robotics, IoT and Data Analytics are proving to be of great value for organizations to achieve these goals as well. Blockchain however is a maturing technology which has also shown high potential to offer tangible benefits to organizations through the use of smart contracts for process automation and access to reliable information.

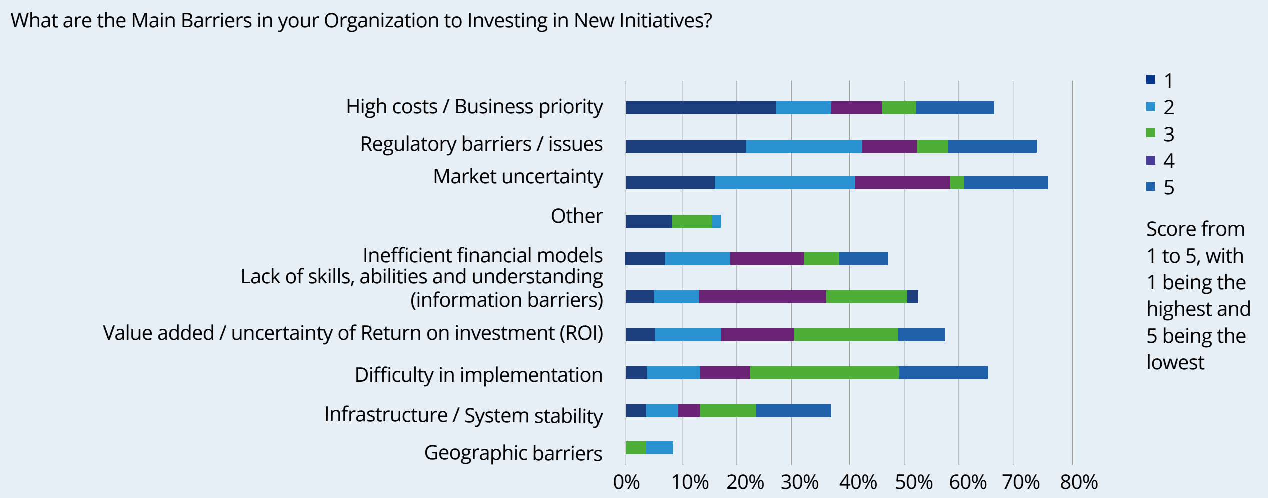
An interesting point of view from Moisés Rosado is that the best way to impulse a Blockchain initiative is by adding value that wasn't there before to an existing process, offering tools to clients that they might not even know they could benefit from. The pitch must therefore be focused towards creating new revenue streams, rather than just cost savings. A clear example would be for energy providers to open a new division for renewable energies, where Blockchain could help users validate that the energy they are purchasing is from green sources.

62. IRENA. (2019). IRENA Innovation Landscape 2019. Abu Dhabi, UAE. Obtained from IRENA web page: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Landscape_2019_report.pdf

Certain users may be willing to pay premium fees for a transparent access and traceability to the origin of their energy consumption.

Despite the benefits offered by new technologies and the critical importance digitalization represents for the industry, it has not yet seen massive adoption in the Energy Sector. Market uncertainty leads as one of the 5 main barriers organizations face when investing in new initiatives according to 76% of consulted experts, closely followed by regulatory issues with 74%. However, neither represent the most critical barrier, which is related to high costs and business priorities, leading with 27% of responses selecting it as the top barrier.

Graph 4.5 – Main Barriers towards Investing in New Technologies



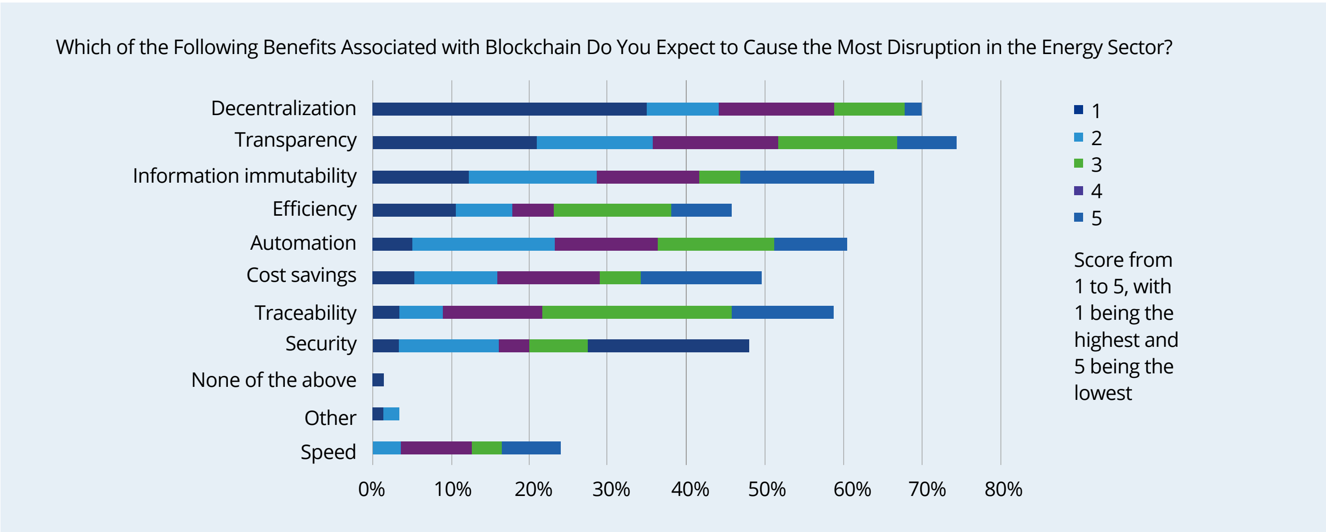
Energy Partnership, 2020

An interesting perspective from Javier Salas is that a lack of modernization from system operators and service providers sends signals to the market by which new technologies are not perceived as a strategic priority for the industry. Rather, investing in mature and proven technologies that can generate profits and mitigate technological risks are seen as the most important consideration. This specific point can represent a significant barrier to investors that have no certainty of the importance digital technology adoption represents for the industry, thus losing business priority for investments in new initiatives involving digital technologies.

Despite these barriers, there are several technologies currently being evaluated within digital strategies across organizations in the Energy Sector. Looking at Blockchain specifically, the market perspective shows an optimistic view, where 89% of experts consider it as a relevant technology for the energy industry and 88% agree that there is a compelling business case for implementing a Blockchain based solution (37% strongly agree and 51% agree). Additionally, there is positive sentiment towards consortium initiatives with over 90% of organizations considering them to be a relevant tool for the sector, a key finding given that Blockchain applications will cause the highest impact through industry-wide solutions.

These results show the relevance of this technology for the Energy Sector, supporting the development of an industry Blockchain ecosystem and further exploration with solutions leveraging this technology. There are several benefits linked to distributed ledgers that have grasped the attention of industry leaders towards harnessing Blockchain-based business models to tackle current challenges. It is also the case that over 80% of experts consider that the sector would lose a competitive advantage if it doesn't adopt the technology, positioning Blockchain as a strategic technology to invest in as part of digital strategies within the Energy Sector. In this sense, organizations that are transforming their business models through new technologies have a first mover advantage by positioning themselves at the center of a new ecosystem, in which they can influence the design and adoption of standards and shape new cross vertical collaborative models and competitive play for second movers to follow (Wilfried Pimenta, IOTA Foundation BD Director, personal communication, April, 2020). Furthermore, consult results showed that 79% of the experts believe there will be a disruption in the energy industry derived from Blockchain, where the main benefits expected to cause it are: transparency, decentralization, data immutability, automation and traceability (74%, 70%, 64%, 60% and 59% respectively). Decentralization and transparency are considered to be the two most critical benefits, ranked at the top of the list by 35% and 21% of respondents. Another point of view, provided by Doug Miller from Energy Web Foundation, is that Blockchain itself won't act as a disruptor; instead it is the Energy Transition which is disrupting the Energy Sector and Blockchain must be seen as an enabler and accelerator of the disruption that is already underway.

Graph 4.6 - Blockchain Associated Benefits to Cause Disruption



Energy Partnership, 2020

As mentioned in the section Main Blockchain challenges and obstacles, one of the most critical challenges for Blockchain adoption from a business perspective is being able to translate industry needs into quality ideas and initiatives that can be solved with this technology. Understanding expected benefits from investing in new technologies and barriers presented when engaging in this type of initiatives is only a first step to overcome this challenge. A second phase involves a market analysis including research on projects and solutions being developed in the industry leveraging Blockchain technology.

A market intelligence process unveiled over 110 Blockchain projects in the sector, varying on their development an maturity levels and covering stages from research all the way to commercially available solutions in the market (see table 4.5). This process was key to identify and categorize Blockchain-based emerging business models for the industry, divided into 4 general classifications: Traceability & Transparency, Market Decentralization, Finance & Payments and IoT & Smart Devices.

These categories are further disaggregated into sub-categories, and they are organized based on the underlying functionality and process Blockchain aims to tackle in the proposed business model. It's important to bear in mind that certain use cases may fall under more than one category, the implemented approach emphasizes the main functionality within a specific business model for its classification. Hereunder a more detailed explanation of each category will be discussed, along with an analysis of certain sub-categories considered to have a high potential for the sector by interviewed experts.

Traceability & Transparency

This business model aims to offer market players accessibility to relevant information that will increase transparency among participants in the distributed ecosystem and traceability throughout specific processes of the value chain. Characteristics such as immutability of the registered events on the ledger and time-stamping of detailed information for recorded transactions are the underlying functionalities for this type of use cases.

Analyzing multiple projects and initiatives that have these two elements as the core value of new business models 5 sub-categories were identified for this area:

Table 4.1 – Traceability & Transparency Business Models

Traceability & Transparency	
Sub-category	**General Description**
Origin Certification	Enables data verification regarding variables and attributes such as output, efficiency, CO_2 emissions, provenance, consumption and other relevant information and details that can be certified by a distributed network instead of a trusted third party.
Digital Claims	The use of consensus mechanisms and cryptography allows participants of a distributed network to create digital versions of certain resources available in the physical world. Digital contracts, identities, signatures, securities, bonds and ownership titles are some examples of digitalization through Blockchain.
Data Management	Decentralized storage of data registered on the Blockchain with a time-stamp recording relevant information (e.g. involved parties, transaction details, exact time, geolocation, etc.) allows participants to monitor, track and give transparency to data that was generated throughout different processes of the value chain.
Asset Management	Enhances visibility and monitoring of physical assets throughout the entire value chain, allowing participants to track and obtain information regarding status, maintenance, servicing requirements, ownership, registries and its complete life-cycle, thus increasing traceability and accountability.
Grid Management and Monitoring	A Blockchain platform can connect market players, associations, regulators and final consumers to provide a distributed exchange of relevant information. Valuable data is unlocked to improve the decision-making process in an increasingly complex grid, including supply/demand balance, congestion management, fee adjustments, grid stability and allocation of distributed resources.

Energy Partnership, 2020

The most advanced use case within this category, and possibly among all others, is Origin Certification. It is also referred to as Energy Attribute Certificates, given that the core value of this sub-category is to offer network participants a verification and validation method to track specific attributes that are relevant to the market, enabling end-to-end certification. Green certificates, for example, aim to record details about clean energy production, including when, where, how and by whom it was generated. This type of solution can unlock incentives to invest, generate and consume clean energy by leaving a verifiable audit trail of these events and establishing the grounds for creating a secondary market where certificates can be transferred, bought or sold. As mentioned by Dietrich Korb, a growing pressure to meet sustainable climate standards in order to reach established goals (along with a significantly more complex grid) require a higher degree of trust and transparency as to how organizations measure their achievements, making Blockchain an interesting solution that could bring benefits to this field.

Data management is another high impact use case for the industry, although it still hasn't reached a high maturity level. The main reason why this type of solutions is still under development and experimentation phases is due to the infrastructure required to deploy a high scale implementation. Data management solutions cover a wide array of use cases, for instance: transaction data in the system, relevant market information, grid supply/demand behavior, registry of installations and generation/consumption from DER's. Certain applications require less modernization in infrastructure than others, making them feasible candidates to test Blockchain-based applications before developing commercially available solutions.

Market Decentralization

Considering decentralization as one of the three main trends in the Energy Sector there are several business models that are focused towards market decentralization.

The key objective of this category is to allow market participants to interact with each other while reducing the need of a third party to act as an intermediary. This is possible thanks to the consensus mechanisms that Blockchain uses to validate transactions among all parties, meaning that trust is placed in the distributed network rather than a centralized institution. 4 sub-categories were identified for this type of solutions.

Table 4.2 – Market Decentralization Business Models

Market Decentralization	
Sub-category	**General description**
Wholesale / OTC Trading	B2B and B2C Interactions through a distributed network ecosystem allows industry players to engage in market operations such as wholesale trading, consumption of locally generated electricity, regional transactions, selling/buying excess renewable energy and risk management processes.
Microgrid / Community Grid	Communities organize themselves to set up a microgrid through a distributed generation infrastructure that allows them to produce their own energy, buy/sell power and settle payments among neighbors without need of a centralized system. This type of systems stimulates DER adoption and consumption of locally produced renewable energy.
Decentralized Marketplaces	Blockchain-based platforms enable a decentralized ecosystem that provides a reliable and efficient mechanism for executing, verifying and recording trading transactions across energy commodities without requiring authentication from a centralized management entity.
Peer-to-Peer Trading	Households act as energy producers and consumers simultaneously (prosumers) through an electricity trading marketplace that enables small-scale energy producers to sell their excess energy independently, without the need of third-party participation. This in turn incentivizes investments in distributed generation infrastructure and market competition for renewable energy.

Energy Partnership, 2020

Market decentralization through the use of Blockchain platforms currently faces significant challenges regarding regulatory frameworks and available infrastructure in the system. However, wholesale energy trading use cases have been identified as the most feasible considering these two factors. Regulations in multiple countries around the world, including Mexico, already take into account wholesale energy trading among qualified generators and consumers; furthermore, distributed generators often have modern infrastructure that facilitates integration with a Blockchain platform.

Alternatively, use cases involving Peer-to-peer trading have generated high expectations and promise in the Blockchain space when thinking of market decentralization platforms. Similarly to Data Management applications, peer-to-peer solutions are still under testing and pilot phases in low-scale scenarios and controlled environments. Relevant projects in this space have been developed in Australia, Germany and the United States, however, there has been no activity in the Mexican market. This type of use case still requires additional efforts from multiple stakeholders in the sector to be implemented (e.g. policy makers, regulators, qualified generators, consumers, etc.). In this sense, P2P trading may have a bigger impact in the medium-to-long term due to the hurdles to scaling caused by the diversity of rules and regulations by jurisdiction.

Renewable credits and wholesale energy trading on the other may have a higher impact and potential for the sector looking at short term opportunities.

Finance & Payments

Business models revolving around financial aspects within the energy industry represent some of the most mature applications for Blockchain, given that the technology emerged as a response to solve challenges in this space.

Enabling features such as programmability through smart contracts and encryption mechanisms to enhance transac tion security are the foundations of innovative solutions that offer alternative mechanisms for payment methods, trading platforms, funding mechanisms, accounting efficiency and process automation throughout various points in the energy value chain. This business model has 4 sub-categories that unlock a variety of use cases for the industry.

Table 4.3 – Finance & Payments Business Models

Finance & Payments	
Sub-category	**General Description**
Project Finance	Crowdfunding platforms leveraging tokenization mechanisms offer investors a financing method to fund small-scale projects such as renewable energy and distributed generation infrastructure. Blockchain offers a low friction alternative which is accessible to broader and cheaper capital pools, while improving transparency and payment liquidity during funding phases.
Payments and Smart Contracts	Smart contracts can be programmed to automate payments across the entire energy value chain. Processes are streamlined, driving efficiency and optimization while leaving a seamless and auditable trail across all network participants and reducing administrative costs involving payment processing and accounting.
Cryptos, Tokens and Stablecoins	Cryptocurrencies offer an alternative payment method for energy services, while Tokens enable asset sharing ecosystems in community projects (e.g. renewable energy infrastructure and storage systems) and tokenization of clean energy production. Additionally, Stablecoins pegged to the value of CECs, bonds and other energy commodities can be traded on a secondary marketplace.
Billing and Settlements	Integrating smart meter infrastructure with smart contracts through a Blockchain platform enables an autonomous metering, billing and settlement in energy services. This functionality introduces an unprecedented cohesion to internal record-keeping processes and enhanced transparency among participants.

Energy Partnership, 2020

Alternative fundraising mechanisms offered by this technology were one of the main drivers behind the Blockchain hype. Crowdfunding platforms based on tokenization can be used to fund energy related projects by offering utility, security, equity or debt tokens to the public, taking out the middleman that manages the platform in popular crowdfunds today, therefore reducing administrative costs. The technology has proven to be an effective tool in this field, but increasing concerns from the market have raised significant barriers for this specific business model. Some key elements to have in mind are: business and governance model, technological viability, legal aspects, regulatory compliance, risk management and controls, set-up costs, fiscal obligations, accounting reports, and operative model design. Some initial local regulations to consider are those emitted by securities, AML/CTF, data privacy, fiscal and accounting authorities.

Another Blockchain application that has been explored and implemented in multiple industries (led by the financial sector) is related to billing and settlements. The underlying distributed ledger technology gives authorized participants a permissioned access to a synced record of transactions, reducing human errors and optimizing settlement processes. The feasibility of a use case within this sub-category will highly depend on the specific process of the value chain in which it will be implemented, as it will require a data source that can be integrated with the proposed Blockchain platform.

There are also mature applications and platforms for use cases involving payments and smart contracts through the use of public Blockchains. This model allows organizations to access new markets, enable digital channels and decrease certain entry barriers or frictions for both small-scale companies and final users. Christine To, director at Stellar Development Foundation, has emphasized potential use cases within this category, where new revenue models can be unlocked through new payments schemes such as micropayments, prepaid packages and subscription fees.

IoT & Smart Devices

As mentioned in previous sections of this report, Blockchain is a tool more likely to reach its full potential when implemented along with other technologies, where IoT and smart devices represent the most relevant complements for use cases in the Energy Sector. Different types of available hardware in the market can be optimized when adding a Blockchain layer to their main functionality, such as providing pseudonymous identities that will empower interactions and coordination mechanisms within an ecosystem or to register relevant data in a distributed ledger that can be leveraged through the use of smart contracts and other technologies like D&A, AI and Big Data. The four sub-categories corresponding to this classification are addressed below.

Table 4.4 – IoT & Smart Devices Business Models

IoT & Smart Devices	
Sub-category	**General Description**
IOT/Smart Devices	IoT and Smart devices continuously generate valuable information which can be registered on the Blockchain. Smart contracts can be programmed to detonate events based on captured data and predefined conditions, such as transactions between devices, credit tokenization, automated payments, asset management and grid decisions.
Smart Homes/Buildings	Blockchain could play an important role in data registry, security, integrity, monitoring and control, serving as a tool to capture primary input information for decision making processes. Smart contracts can serve as a communication channel among IoT and Smart devices to enforce rules and automate certain actions within Smart Homes and Buildings.
Energy Storage/Batteries	Stationary batteries and energy storage facilities can be used to provide stability and flexibility to the grid. Blockchain offers a tool to better exploit this type of DER's through coordination mechanisms in an increasingly complex decentralized system with a growing number of participants and devices interacting in the market. Visible opportunities for energy storage include demand response to counter low generation and peak consumption hours, investing incentives for individuals, automated grid charges/discharges and integration with other DER's.
Electric Vehicles & E-Mobility	A distributed network ecosystem enables interactions among EV and E-mobility users by assigning identities to the vehicles and providing an integration for charging infrastructure. A Blockchain platform can coordinate vehicle load and discharge, dynamic price-setting and managing charging point locations and their saturation. Additionally, smart contracts can facilitate M2M payments and settlements, drive price competitiveness and incentivize drivers through token-based mechanisms.

Energy Partnership, 2020

IoT and smart devices should not only be perceived as a specific use case limited to this category, but rather as a fundamental tool that enables multiple Blockchain-based business models by acting as a primary source of information that is then recorded on the distributed ledger. In this sense, solutions across other categories are likely to leverage certain functionalities of this sub-category. However, there are use cases where the main purpose revolves around IoT and smart devices; it is important to identify what role these devices play within a proposed business model when classifying a use case. Furthermore, IoT technology is currently perceived as a maturing technology as well, which can pose a double challenge when designing a business model that seeks integration with Blockchain.

Business models that are focused on energy storage systems and batteries are expected to have a high impact for the industry in accordance with the evolution of these technologies. Blockchain could act as a coordination mechanism for integrating these resources into the grid by providing transparent and reliable information to network participants, which will enhance decision making processes involving stored energy. Interesting applications emerge when thinking of a Blockchain platform that connects information from electric vehicle batteries with the grid to incorporate them as additional DER's that can be exploited. However, energy storage technology has yet to develop and become cost effective in order to be massively adopted by the market, until this happens Blockchain does not seem to offer a compelling business case for developing a solution.

4.5 Existing Blockchain applications in the Energy Sector

During the market analysis process for the use of Blockchain technology in the Energy Sector at an international scope several projects and initiatives leveraging this technology at some degree were identified. Project maturity levels vary from research and development to commercially available solutions. Some of the mentioned initiatives may no longer be active, this can be due to a completion of the PoC or testing phases initially proposed or survivability struggles from small players in the market, nonetheless they are included as relevant use cases to consider when assessing applications for the industry.

Furthermore, several projects from multinational private organizations and public institutions were identified within their digital and innovation strategies. However information related to these initiatives is not yet publicly available, making it of the utmost importance to stay alert for official communications and press releases from governments and the private initiative as confidential regarding PoC's, pilots and testing phases are made available to the general public. The following table offers some of the studied use cases and initiatives throughout the development of the report.

Table 4.5 – Blockchain Projects and Initiatives in the Energy Sector

Blockchain projects and initiatives in the Energy Sector				
#	Company	Country	Category	Use Case
1	Bankymoon	South Africa	Finance & Payments	Through smart meters, users can pay their electric bills with instant settlements, also enables anybody to directly donate to a meter of their choice (schools, hospitals, shelters, etc.).
2	BAS Nederland	Holand	Finance & Payments	BAS became the first energy company to accept Bitcoin as a payment method.
3	Climate Chain Coalition	Canada	Finance & Payments	An organization that promotes Blockchain related skills and capabilities to help mobilize funding for climate solutions.
4	Climate Coin	Switzerland	Finance & Payments	Cryptocurrency based in Ethereum Blockchain. This crypto is used to raise funds for environmentally inclined projects.
5	Elegant	Belgium	Finance & Payments	Elegant is a Belgium-based green energy supply company that has started to accept bitcoin as a payment method.

Blockchain projects and initiatives in the Energy Sector				
#	**Company**	**Country**	**Categroy**	**Use Case**
6	Global Grid	Mexico	Finance & Payments	A platform that aims to help large photovoltaic project developers in Mexico raise capital for required infrastructure and execution.
7	Grid +	USA	Finance & Payments	The Grid+ Energy initiative seeks to provide final customers access to electricity at wholesale rates, lowering prices and incentivizing the adoption of energy efficient resources.
8	ImpactPPA	USA	Finance & Payments	A decentralized utility platform that allows consumers of energy to "pre-pay" for electricity from a mobile devices.
9	Marubeni	Japan	Finance & Payments	In partnership with WePower, Marubeni is accessing renewable producers to buy their energy directly from them.
10	Prosume	Italy	Finance & Payments	A Blockchain platform that allows users to exchange energy from different sources through their decentralized and self-regulated monitoring system.
11	R3	USA	Finance & Payments	Offers solutions that enables businesses across multiple industries to transact directly and reduce transaction and record-keeping costs and streamlining business operations.
12	Solar Coin	USA	Finance & Payments	Seeks to incentivize solar electricity generators by rewarding them with cryptocurrencies for each MWh produced.
13	Sun Exchange	South Africa	Finance & Payments	A P2P leasing platform that allows users from anywhere in the world to own solar energy-producing cells through tokenization.
14	The Energy Blockchain exchange	Canada	Finance & Payments	Guild One, in collaboration with R3, created EBX, a platform for energy transactions such as royalties, joint ventures, AFEs and road use allowances.
15	IOTA Foundation	Germany	IoT & Smart Devices	Enables and supports the development of smart energy ecosystems through IoT infrastructure in traceability, smart charging, micropayments, smart mobility, P2P flexibility, smart buildings and smart homes.
16	MyBit	Switzerland	IoT & Smart Devices	MyBit created marketplace for individuals to invest in IoT and Smart Devices, allowing them to generate income though these revenue generating machines.
17	Pylon Network	Spain	IoT & Smart Devices	Provides access to a neutral energy database where market players and other agents can interact to offer added value services in the system.
18	Share & Charge	Switzerland	IoT & Smart Devices	An Open Charging Network (OCN) that serves as a B2B marketplace for the EV charging community that allows users to connect with each other.
19	Slock.it	Germany	IoT & Smart Devices	Enables devices to access data in the Blockchain to interact with each other and other network participants to offer data control and decision support for large scale IoT infrastructure.
20	Tennet	Holand	IoT & Smart Devices	Provides an interconnected pool of electric vehicles and charging stations that can coordinate interactions through a Blockchain platform.

Blockchain projects and initiatives in the Energy Sector				
#	**Company**	**Country**	**Category**	**Use Case**
21	Austrian Power Grid (APG)	Austria	Market Decentralization	The Austrian Power Grid and Energy Web Foundation launched a PoC process for grid flexibility solutions that will enable small-scale DERs to participate in frequency regulation.
22	Brooklyn Microgrid	USA	Market Decentralization	A neighborhood marketplace PoC implemented by Siemens and LO3 that enables residents to sell their excess solar energy to other residents who prefer buying from renewable sources
23	Drift	USA	Market Decentralization	Their technology combines each unit of green energy produced with real time energy use to provide traceability of where it comes from.
24	Energy Web Foundation	Germany	Market Decentralization	Provides open source tools for DApp development to accelerate innovation and testing in energy traceability and grid flexibility use cases, while reducing efforts required to implement a real Blockchain business solution.
25	HashGraph	USA	Market Decentralization	Driving to create a peer-to-peer energy trading and microgrid management platform.
26	Lition	Germany	Market Decentralization	Development of a scalable public-private Blockchain that powers the Lition Energy Exchange for open and direct energy trading.
27	LO3 Energy (Exergy)	USA	Market Decentralization	LO3 created the Pando platform, offering a simple way to coordinate consumers to buy and sell local energy and optimize the grid by unlocking a local energy marketplace.
28	OLI Systems GmgH	Germany	Market Decentralization	Implementation of diverse pilot projects that enable consumers and prosumers with decentralized generation to become active players in the grid.
29	Ponton GmbH	Germany	Market Decentralization	Ponton has developed several Blockchain related projects, highlighting a trading platform for power, gas and CO2 certificates.
30	Power Ledger	Australia	Market Decentralization	Developed a platform to make renewable energy markets more efficient by enabling user to transact energy, trade environmental commodities and invest in renewables.
31	Siemens Energy	Spain	Market Decentralization	Siemens has engaged in multiple Blockchain initiatives, highlighting a platform for producers and consumers in Spain to carry out energy transactions.
32	Sonnen	USA	Market Decentralization	Launched a pilot project to show how decentralized home storage systems can be networked, using Blockchain technology to stabilize the power grid
33	WePower	Lithuania	Market Decentralization	Powers a marketplace that connects companies with generators to buy green energy at competitive rates with full transparency.
34	Blockchain for climate foundation	Canada	Market Decentralization	Development of a platform to enhance the authenticity, validation and trading of carbon credits on a decentralized marketplace.

Blockchain projects and initiatives in the Energy Sector				
#	Company	Country	Category	Use Case
35	Carbonex	France	Market Decentralization	Tokenization of carbon credits using open Blockchain technology and a carbon credits platform.
36	Conjoule	USA	Market Decentralization	Development of a decentralized energy marketplace where participants can transact energy, capacity and flexibility under P2P models.
37	Greeneum	Israel	Market Decentralization	Acceleration of the Energy Transition by leveraging Blockchain technology and AI, offering digital assets that are associated to profitable green energy projects.
38	New Era Energy	United Kingdom	Market Decentralization	A carbon trading and measurement platform that permits the network to monitor emission levels and buy carbon offsets.
39	CarbonX	Canada	Traceability & Transparency	Creation of carbon tokens on a private Blockchain to validate provenance and ensuring security and transparency to all transactions.
40	Cincel	Mexico	Traceability & Transparency	Lumit has developed Cincel, a platform to provide Proof-of-Ownership for digital assets through Blockchain technology which can be used for certification purposes.
41	Emmi	Australia	Traceability & Transparency	Offers a platform that offers traceability, security and transparency in carbon emission reductions while linking performance to credit risk and allowing stronger financial returns.
42	Energy Blockchain Labs	China	Traceability & Transparency	A Blockchain platform based in green asset management that allows users to manage carbon credits and enable CER issuance.
43	Flexi DAO	Spain	Traceability & Transparency	Offers a software platform for energy retailers to use Blockchain technology as a means to provide energy data management tools.
44	Grid Singularity	Germany	Traceability & Transparency	A grid management agent that offers an open source platform to build energy exchanges, enabling local marketplaces that interconnect to form a transactive grid.
45	Mercados eléctricos	El Salvador	Traceability & Transparency	Developed a digital marketplace platform in collaboration with Energy Web for verified renewables generation in Central American I-REC markets.
46	Pacific, Gas & Electric Company	USA	Traceability & Transparency	Engaged in testing activities of Blockchain technology to improve customer engagement and grid efficiency.
47	Phineal	Chile	Traceability & Transparency	Launched a pilot for solar energy traceability in Chile to enhance transparency during the monitoring of reported greenhouse gas emissions and providing registries for the national carbon market.
48	Poseidon Foundation	Singapur	Traceability & Transparency	Poseidon put together Blockchain technology and artificial intelligence in order to allow organizations and customers to quickly analyze their carbon footprint data.
49	Swytch	USA	Traceability & Transparency	The Swytch platform automates transactions of the REC creation process, depositing the certificates in a permanent and immutable record.
50	Veridium Labs	Hong Kong	Traceability & Transparency	A collaborative initiative that developed a platform to automate environmental impact accounting and create a marketplace for digitized environmental assets.

A further in-depth analysis will be provided for a select number of projects that show high potential impact for Blockchain-based solutions in the Energy Sector. Priority was given to projects with strong international presence and global reach, as well as solutions being developed in the Latin American market to showcase short-term opportunities for Mexico.

Blockchain use cases at an international level

Energy Web Foundation

energy web

Energy Web is a global nonprofit accelerating a low-carbon, customer-centric electricity system by unleashing the potential of Blockchain and decentralized technologies. The Energy Web Foundation is deploying the Energy Web Decentralized Operating System (EW-DOS), an open-source environment where enterprise-grade solutions can be built, tested and deployed by market participants such as customers, grid operators, service providers and retailers. An important component of the EW-DOS is the Energy Web Chain, a public Blockchain platform governed by participating market players to ensure compliance with industry standards. There are currently two software development toolkits (SDK's) available to accelerate the deployment of Blockchain-based solutions in the Energy Transition: traceability and tracking for renewable energy (EW Origin) and integration of Distributed Energy Resources (DERs) into the grid (EW Flex).[63]

One clear example of how EWF is accelerating decentralized solutions in the Energy Sector is through a collaboration with TEO (The Energy Origin), a French start-up incubated within the multinational electricity utility Engie. TEO developed a decentralized application (dApp) on the EW Chain that offers an improved traceability and transparency of green energy in the grid by emitting Energy Attribute Certificates in a trusted and decentralized ecosystem.[64] In addition to this functionality, it allows renewable generators and corporate buyers to match their supply-demand requirements in a more efficient way by choosing their renewable energy sources and geographic location to incentivize local consumption.

Additionally, EWF is working with various EWF Members in Latin America to develop digital renewable energy procurement platforms using EW Origin that promotes the International Renewable Energy Certificate (I-REC) Standard, including Mercados Eléctricos in El Salvador and Fohat in Brazil. These platforms are, respectively, in pilot and initial development phases to support commercial I-REC transactions that help corporate buyers meet their proof of impact needs.

Siemens Energy

SIEMENS energy

Innovation and digital transformation have been a key strategic element for Siemens Energy, taking lead of the main trends in the Energy Sector today represented by the 3D's. Siemens has opted for a holistic approach towards Blockchain adoption, which considers the integration of new technologies, enabling applications and innovative business models. Emma Díaz Ruiz, Digitalization Specialist in Siemens Energy, has emphasized how a successful Blockchain implementation lies behind mixing three key ingredients correctly: 3 parts represented by the development of a digital infrastructure to support new technologies, 2 parts correspond to building an ecosystem for digital solutions to thrive and, lastly, 1 part consisting of the Blockchain solution itself, which can't survive without the other components.

63. Energy Web. (2019). EW-DOS: The Energy Web Decentralized Operating System An Open-Source Technology Stack to Accelerate the Energy Transition. Berlin, Germany. Obtained from Energy Web Foundation web page: https://www.energyweb.org/wp-content/uploads/2019/12/EnergyWeb-EWDOS-VisionPurpose-vFinal-20200309.pdf
64. Energy Web. (2019). Blockchain: TEO (The Energy Origin) is the first application to migrate onto the Energy Web Chain. Zug, Switzerland. Obtained from Energy Web Foundation web page: https://www.energyweb.org/2019/09/19/blockchain-teo-the-energy-origin-is-the-first-application-to-migrate-onto-the-energy-web-chain/

One of the most relevant projects developed by Siemens, in collaboration with LO3, was the creation of a digital grid called the Brooklyn Microgrid. This initiative aimed towards testing the feasibility of a Blockchain platform that allows a neighborhood community to produce, consume and purchase solar energy in a peer-to-peer trading platform. Although the pilot is over, its main propose was to connect people in one of NYC's neighborhood to sell their excess solar energy and provide more energy generation options, thus incentivizing renewable and local energy consumption.

Likewise, Siemens has also developed the e-ing3ni@ Blockchain energy trading platform in Spain, where users can buy and sell green energy. This network has the objective to connect energy producers and consumers in a decentralized marketplace in order to empower final customers in the energy market by giving them access to a wider array of purchase options, giving them the capacity to choose the type of energy they consume. The platform solves transparency and traceability challenges of energy offered in the market by verifying and validating the generation source, thus increasing trust for customers. Similarly, it allows market players such as producers, consumers and retailers to manage their master data more efficiently, access reports to know the operation´s results and facilitates the integration of ERP systems for payments and settlements.[65]

Corda

The Corda open source Blockchain platform from R3 allows businesses to develop solutions under a strict privacy model to engage in secure and seamless transactions. Energy companies leverage R3's technology to solve significant challenges in the industry, such as low trust among counterparties, manual documentation practices and low traceability of assets.[66] Some solutions being explored on Corda include identity verification to comply with training requirements and permits, tracking of renewable energy certificates, proof-of-ownership for energy resources and digitization of trading marketplaces for commodities.

One example is the Energy Blockchain Exchange (EBX) platform for energy transactions developed by Guild One in collaboration with R3. It is designed to offer a secure

and automated platform for complex multiparty energy transactions in safe and rapid way while leaving a strong audit trail. Industry market players can securely share smart contracts, optimize payment settlements and guarantee revenue rights, opening way to multiple innovative business models for the industry.[67]

IOTA

The IOTA Foundation is a not-for-profit foundation ("Gemeinnützige Stiftung") incorporated and registered in Germany. It seeks to support the development and standardization of new DLT's, including the IOTA Tangle, a type of DLT specifically designed for the Internet of Things (IoT) environment. It is an open-source protocol facilitating novel Machine-to-Machine (M2M) interactions, including secure data transfer, fee-less real-time micropayments, and the collection and dissemination of sensor-based and other types of 'oracle' data. As of June 2020, the IOTA Foundation consists of a global team of over 110 individuals distributed across 23 countries.

The increasingly complex grid requires a secure and scalable platform to coordinate devices connected to the network. Therefore, IOTA has established smart energy as one of its main verticals, collaborating with its partner ecosystem to develop use cases such as, but not limited

65. Siemens. (2019). e-ing3ni@ Platform. de Siemens Sitio web: https://new.siemens.com/global/en/company/topic-areas/energy-transition/e-ingenia.html
66. R3. (2019). Customers Energy. New York, US Obtained from R3 web page: https://www.r3.com/customers/energy/
67. GuildOne. (2019). ConTracks: GuildOne's Smart Contract Engine. Calgary, Alberta. Obtained from Guildone web page: https://guild1.co/contracks-smart-contract-engine-on-block-chain/

to, secure real time data monitoring from smart energy agents, traceability of energy attributes (local, sustainable) and REC/GoO markets, M2M micropayment for smart energy assets, Plug & Charge and Green Smart charging, P2P flexibility energy market and positive Energy Districts/Islands.[68]

A prominent example of these efforts is the +CityxChange (Positive City ExChange), a smart city and positive energy district project that has been granted funding from the European Union's Horizon 2020 research and innovation programme. The Norwegian University of Science and Technology (NTNU) is the host and leads the +CityxChange consortium together with the Lighthouse Cities Trondheim Kommune and Limerick City and County Council in Ireland. 29 other partners include the local TSO, District Heating operator, city testbeds, real estate operators, EV rental companies and smart charger solutions. The project develops, tests and facilitates the adoption of innovative technologies to create self-sustainable energy districts. IOTA technology is conceived as a data integrity layer and M2M micropayment for local P2P energy trading and a real-time flexibility market model. It also enables the development of innovative digital services such as seamless E-mobility as a service (emaas) to help citizens identify the most efficient transportation option according to their needs.[69]

WePower

The WePower network operates in the European and Australian wholesale energy market by offering Virtual PPA's to market players integrated to the platform, connecting companies directly with green energy generators that offer competitive rates with full transparency. It is currently available to large energy users such as second tier retailers and large corporate customers but can also serve as a secondary marketplace for smaller corporate customers. The platform allows retailers to obtain an entire PPA (or strips of it) in less time and with a better pricing through a more responsive process flow for project financing, thus making projects much faster and efficient. All PPA's executed on the platform are adjusted to be settled according to the corresponding marketplace, where financial risks also become a significantly relevant factor.[70] Nikolaj Martyniuk, CEO and founder of WePower, describes this digital solution as a convergence between Blockchain technology and legal aspects involved in this type of contractual interactions.

Emmi

An Australian start up that leverages Blockchain technology to create a decentralized platform for a carbon market. Its main objective is to address structural and risk issues that currently represent a challenge for obtaining capital flows into climate solutions. Michael Lebbon explains that there is currently over $10 trillion dollars of unpriced climate risks across global balance sheets, thus Emmi offers the financial sector a carbon rating network in order to help decarbonization by identifying, quantifying and pricing climate related risks through a mechanism called the Emmi Score. The platform creates an aggregation of carbonization data that participants can trust to evaluates climate risk variables depending on an organization's performance related to their sustainability goals, allowing organizations to obtain better financing options as a reward for decarbonization while financial institutions can reduce the cost of capital by correctly identifying relevant risks in sustainability terms.[71]

Phineal

A Chilean startup that leverages Blockchain technology along with artificial intelligence to develop solutions applied to the energy system to address climate change. They have published multiple articles researching technology use cases within the industry and developed three Blockchain projects to achieve their goals. The first of them is Central, specialized in building isolated photovoltaic systems that operate under distributed generation schemes. The second initiative is the Solar Robotics platform that integrates advanced manufacturing systems for energy storage and E-mobility equipment to provide an efficient energy management mechanism. Lastly is PhiNet, an information platform connected to a network of metering stations to provide services to the solar energy industry.[72]

68. IOTA. (2019). Opening Data for Smarter Communities. Berlin, Germany Obtained from IOTA web page: https://www.iota.org/solutions/smart-city
69. Main, D. (2019). Developers community update: IOTA & +CityxChange Berlin, Germany Obtained from IOTA web page: https://blog.iota.org/iota-cityxchange-community-update-85f43894bcca
70. WePower. (2017). The easiest way to buy green energy directly from producers and reach your energy sustainability goals. Vilnius, Lithuania. Obtained from WePower web page: https://www.wepower.com/
71. Emmi. (2018). The greatest source of systemic risk to global capital markets is climate change. Melbourne, Victoria. Obtained from Emmi web page: emmi.io
72. Phineal. (2013). Tecnología inspirada en la naturaleza. Santiago, Chile. Obtained from Phineal web page: https://www.phineal.com/

Lumit

This Mexican startup specializes in Blockchain technology through education, consulting and development of solutions for private organizations, NGO's and governmental institutions. Their Blockchain-based cloud solution, Cincel, allows a streamlined digitalization of any type of contract or document that can be signed with complete legal compliance.[73] This is achieved by leveraging the electronic cryptographic signature available to all Mexican citizens, or through an autograph signature enabled by their platform. This functionality can also be used to digitally certify documents such as Renewable Energy Certificates, granting enhanced efficiency and control to users when managing assets represented in the digital world.[74]

4.6 Potential use cases for Mexico

The previous section shows several Blockchain initiatives, projects, applications and solutions for the Energy Sector. Although these examples can serve as a benchmark as to how the technology can be used in the industry, there are additional considerations that play an important role when assessing use cases, including infrastructure's current state, industry maturity and governance, macroeconomic factors, political context and other social and cultural aspects that can represent significant barriers for innovation. In order to identify relevant factors applicable to Mexico, a group of experts were invited to participate in a Digital Workshop designed to analyze and qualify potential Blockchain applications with the highest impact and feasibility, with a perspective aligned to the Mexican Energy Sector. The following graph shows the process used to select candidate use cases for consideration:

Graph 4.7 – Methodology for Use Case Selection

Energy Partnership, 2020

A total of 35 subject matter experts attended the workshop, 53% from Mexico to provide insights and experience from the local market and the remaining 47% from a diverse selection of countries, including Germany, United States, Italy and the UK. The group was selected carefully in order to include diversified profiles, having actors from the private initiative, public sector, foundations, associations/organizations, academy and startups (representing 26%, 6%, 11%, 14%, 12% and 31% respectively). Additionally, expertise backgrounds included Energy (34%), Digitalization (32%) and Blockchain (34%), balanced in such a way to include perspectives from these 3 highly relevant fields.

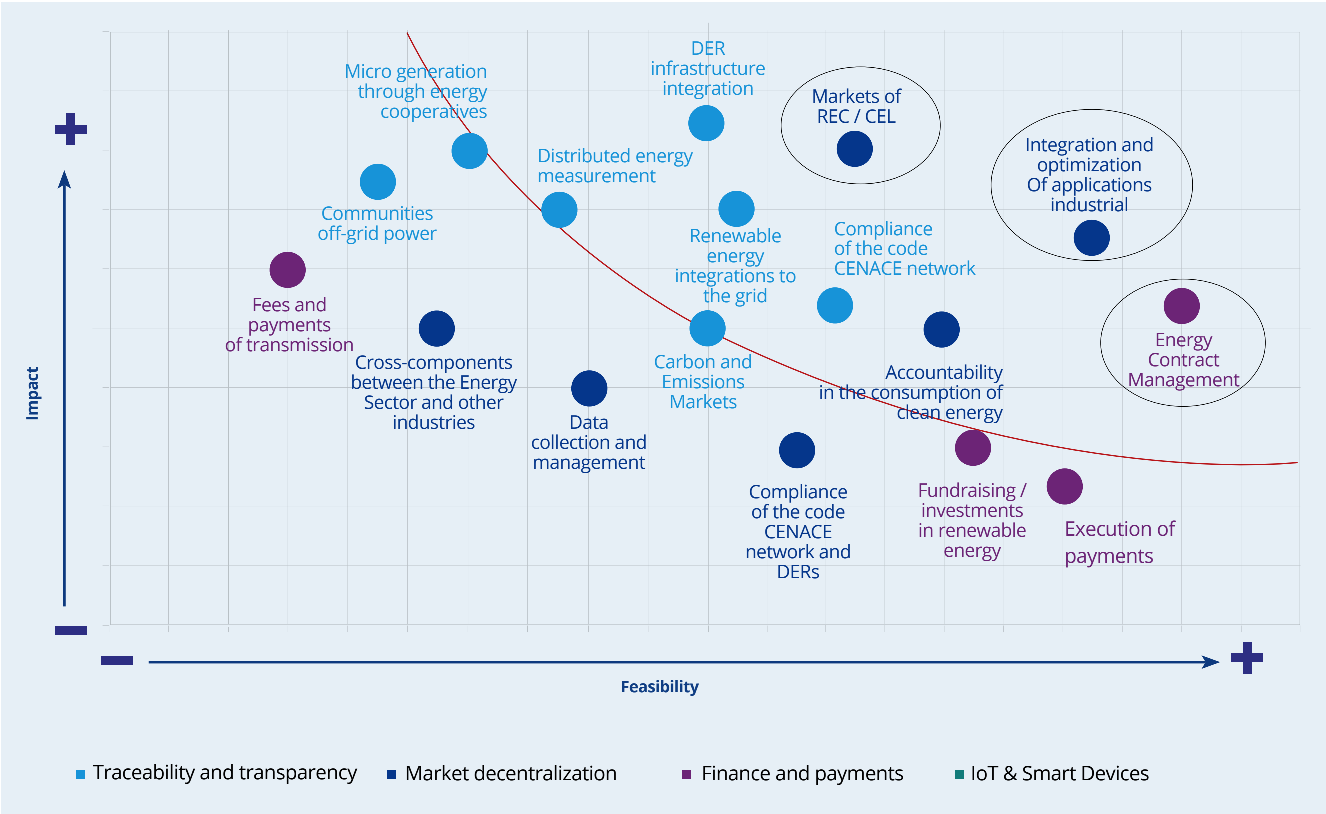
Participants were distributed into 3 separate working groups to discuss current state process flows where Blockchain becomes relevant, critical pain points within the identified processes and potential use cases to solve them. Lastly, separate sessions where held with high-level public officials from two of the most important govern-

73. Lumit. (2017). Soluciones Blockchain para México y LATAM. Mexico City, Mexico. Obtained from Lumit Blockchain web page: https://www.lumitblockchain.com/language/es/
74. Lumit. (2019). Cincel. Mexico City, Mexico. Obtained from Lumit Blockchain web page: https://www.cincel.digital/

ment bodies in the Mexican Energy Sector. Findings and results from the workshop sessions were presented to obtain their personal opinion, perspectives and additional contributions, which have also been integrated in the present section.

First, experts brainstormed through several current-state processes in the energy value chain where they considered Blockchain to be a relevant tool based on an impact-feasibility analysis. An initial assessment using the framework provided in section 3.6 was used to measure the potential impact the technology could have in a given process. In Parallel, key elements where pointed out such as: associated costs, regulations, infrastructure, access to skills and capabilities, potential benefits and estimated effort for implementation. Said elements were the basis to evaluate the feasibility of implementing innovative solutions, such as Blockchain, within the identified process. Graph 4.8 shows the results of the current state understanding and process flow selection.

Graph 4.8 – Current-State Process Flow Selection



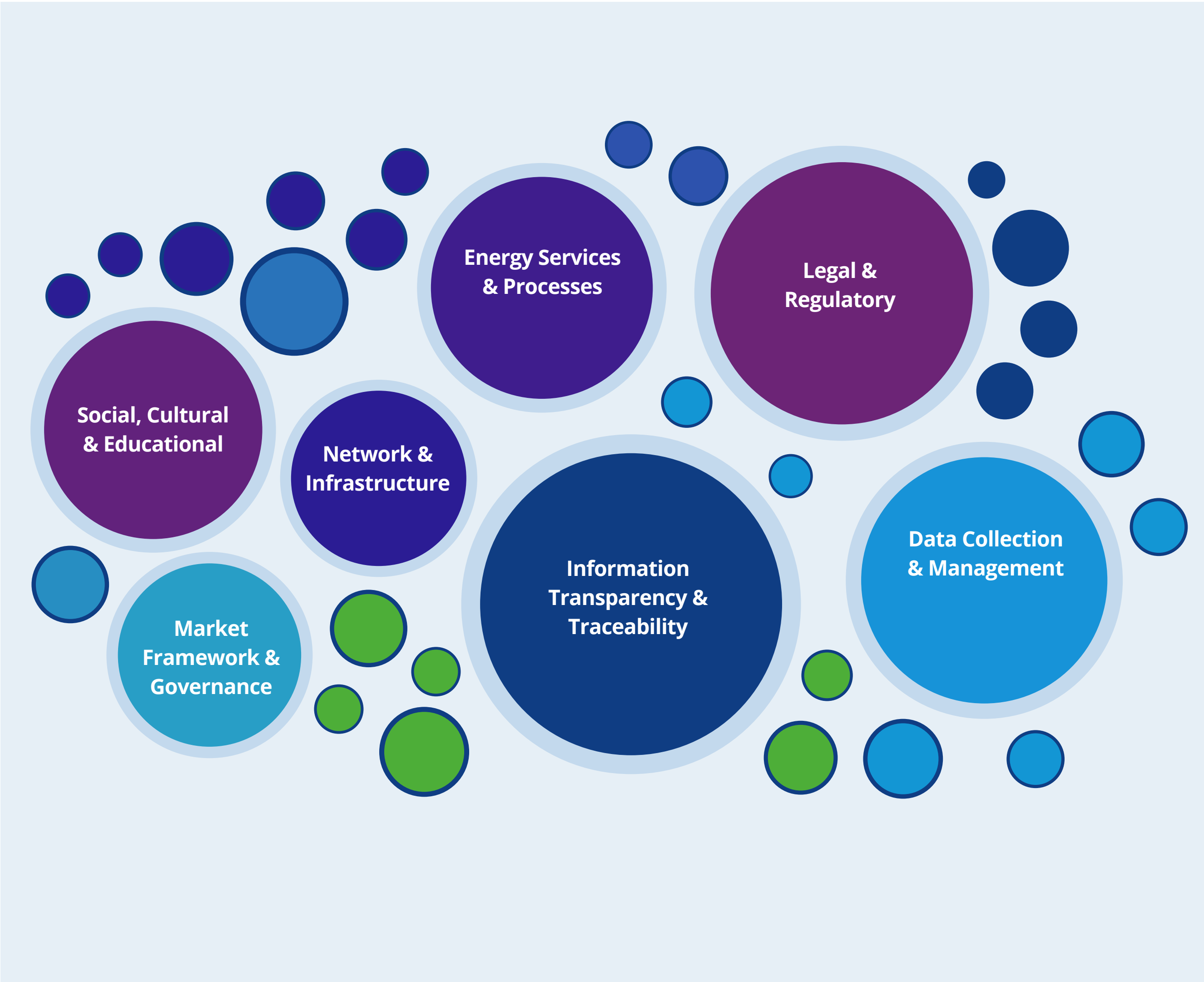
Energy Partnership, 2020

Experts identified 7 processes related to Traceability & Transparency use cases, 7 to Market Decentralization and 4 to Finance & Payments. No processes for IoT and Smart devices were proposed by experts, mainly due to Mexico’s lack of market maturity regarding this type of infrastructure, however several of the future-state processes will require integration with these technologies for them to be successful. The three encircled processes were selected for exploring potential Blockchain use cases.

The first is the CEL Mexican Marketplace (comparable to international REC markets), which would have a high industry impact with certain feasibility constraints due to regulations and adoption of a standardized framework. This process can further be complemented with Accountability for Clean Energy Consumption. Another process is the Integration & Optimization of Industrial Applications into the grid; although it has a lower impact than the previous one, feasibility does increase significantly given that solutions can be developed and tested between private organizations while complying with the current regulatory frameworks. Lastly is Energy Contract Management, with high feasibility as Blockchain will only help streamline existing processes to improve efficiency but with a lower impact due to several available tools for automation in the market.

Secondly, based on these three process flows, while also considering other processes that are highly related to them, experts identified pain points that the industry is currently facing. All mentioned pain points were categorized into 7 groups, depending on what part of the process it is focused on. Graph 4.9 shows all groups in different sizes depending on how many pain points were mentioned in total for each corresponding category, where those related to Data Transparency & Traceability lead issues the industry is facing, followed by Legal & Regulatory affairs, Energy Services & Processes, Social, Cultural & Educational matters and finally a tie between Grid & Infrastructure and Market Frameworks & Governance.

Graph 4.9 – Pain Point Prioritization



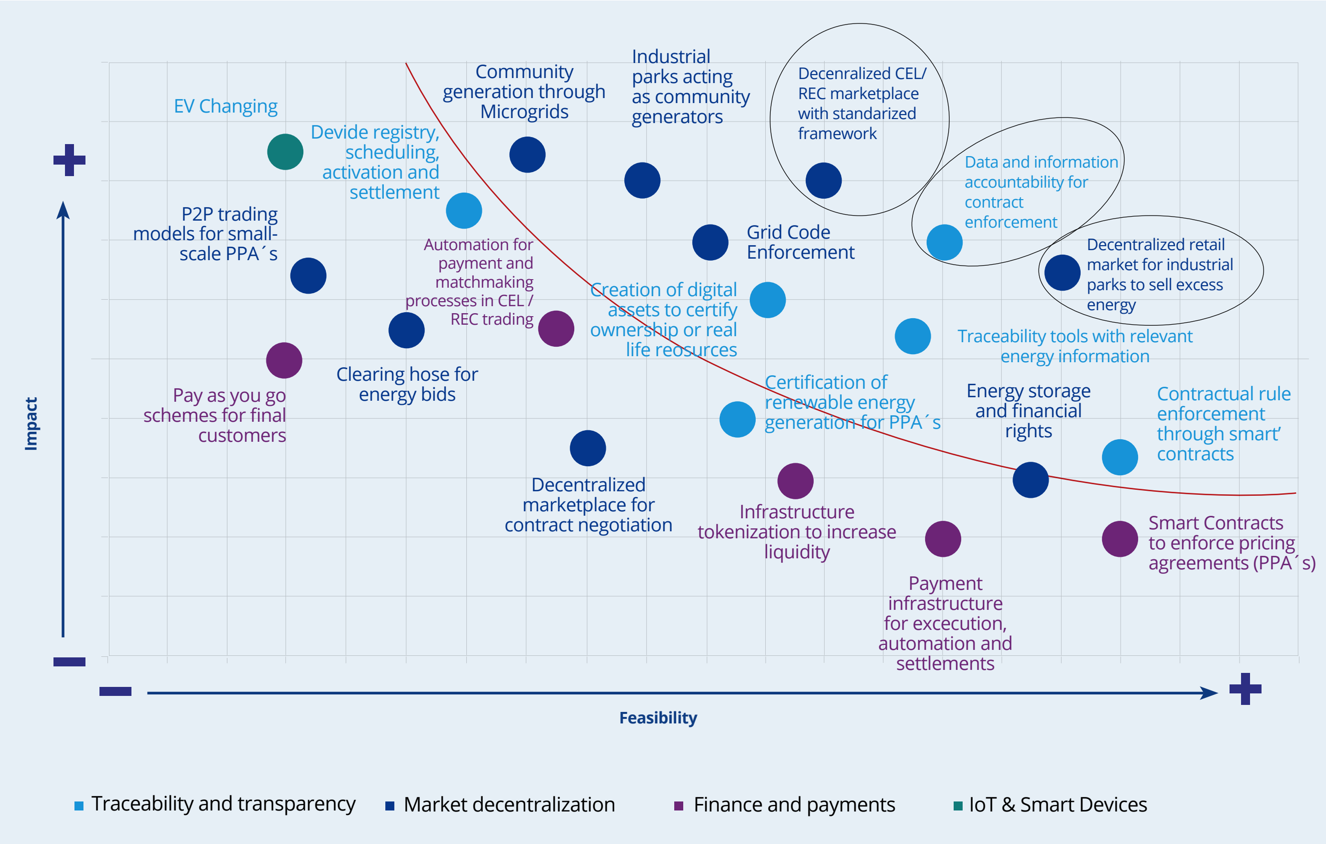
Energy Partnership, 2020

All pain points within the previous groups correspond to specific processes, however they are first presented from a high level perspective to provide sensitivity of the challenges that the industry is facing. Section 4.7 will include further details of the relevant pain points for each of the identified processes. Each pain point was also qualified depending on how critical it is for the industry today, where some of the top priorities were found in the lack of transparency on how available information is obtained, price and quality of available energy services, obsolete infrastructure for data collection and scarce access to human capital for implementing digital technologies in the Energy Transition.

Next, having selected a current-state process flow along with its high priority pain points to focus on, participants began to identify potential use cases that could be implemented in the Mexican industry. This stage also included an evaluation of all the proposed use cases through an impact-feasibility analysis similar to the one used for selecting current state processes.

The main difference between the two frameworks lies in the variables used for selecting the most relevant use cases. Here, impact is measured by looking into the challenges it is seeking to solve (e.g. lack of transparency, inefficient intermediaries and data monitoring) and strategic considerations for industry leaders (e.g. life-time value, market penetration and disintermediation). Feasibility on the other hand is evaluated through both a business perspective (e.g. implementation costs, stakeholder benefits, risk reductions) and technological considerations (e.g. data accessibility, infrastructure integration, interoperability). Potential use cases identified using this framework are presented in the following graph:

Graph 4.10 – Potential Use Case Identification



Energy Partnership, 2020

During this process the leading category for potential use cases identified was Market Decentralization, with a total of 9 candidates. The following category was Traceability & Transparency with 6 proposals, followed by Finance & Payments with 5 and in last place was IoT & Smart Devices with only 1 use case. These results can be supported by graph 4.6, which shows that the two main benefits industry leaders expect from Blockchain technology are related to transparency and decentralization. Once all identified use cases were qualified and mapped out, three of them were selected with highest potential for the Mexican Energy Sector: a decentralized CEL / REC marketplace with a standardized framework, data and information accountability for contract enforcement and a decentralized retail market for industrial parks to sell excess energy. It's important to clarify that several use cases shown in graph 4.10 can be complementary to the 3 selected, as they are related to the same current state process. Further detail of each use cases will be presented in the following section.

4.7 Applications identified within the Mexican Energy Sector

This section will provide an analysis for each of the selected use cases. The complete selection process will be reviewed, including current state process flow selection, pain point identification and potential use case qualification applicable to each selected application. Afterwards an explanation of the selected use case will be given, along with a review of complementary use cases proposed, potential benefits, main challenges and key action items for industry adoption.

Decentralized CEL / REC marketplace with standardized framework

The first current state process selected was the CEL market, which experts identified as relevant for potential impact since it has many opportunities in which Blockchain could create feasible solutions. Blockchain could make information within the CEL market traceable, transparent and immutable, increasing efficiency and reducing costs. The process could be simplified by having transparent and reliable information from the generation, issuance and commercialization of CELs, significantly reducing the need of verifications and clarifications among participants.

Blockchain implementation in the CEL market is often seen as a quick win due to the nature of the process in which transactions occur among numerous participants, therefore organizations require transparency of the entire operation. It is also considered to be a feasible process for Blockchain implementation since there are successful international use cases for similar REC markets and Mexico already has a standardized framework and regulations in place for a local marketplace of this nature.

This process currently consists of multiple parties sharing information and having to verify integrity of reports since there are multiple input sources. A CEL is issued through the following process: First, CRE receives a report from CENACE of the amount of clean energy produced from a specific generator, then the CRE creates the CEL and grants it into the account of the corresponding generator; this takes up to 10 days according to current regulations. After an additional 10 days the renewable generator receives their CEL. In some occasions the information shared by CENACE to the CRE is not the same that the generator has, so there can be an additional process in which the CRE compares the information received from different sources and can request for clarifications. Once the CEL is issued, it goes into the market where participants with the obligation to buy them can present buying bids and the clean energy generators present selling bids. Finally, the CRE analyses which players have complied with their clean energy obligations (CRE, 2016).[75]

In the workshop, experts segmented the CEL marketplace process into 5 high level stages that are important to keep in mind for the development of a Blockchain solution. These stages don't comprehend the entire process for the CEL marketplace, but they are key steps to consider for understanding how Blockchain could be implemented.

Graph 4.11 - CEL Market Current-State Process Flow

1. Define the information that must be captured and registered in the platform (e.g. source, location, authorization, involved parties)
2. Establishment of data capture points for renewable energy generation and consumption (e.g. DER´s, prosumers, EV´s).
3. Assignment of CEL .to market players based on pre-defined sustainability goals and objectives
4. Identification of potential buyers and sellers that will interact within the proposed DEL trading Marketplace.
5. Matchmaking process between buyers and sellers for generators to offer their CELs and third parties to bid for them.

Energy Partnership, 2020

75. CRE. (2016). Preguntas Frecuentes sobre los Certificados de Energías Limpias. Mexico City, Mexico. Obtained from Mexican Government web page: https://www.gob.mx/cre/articulos/preguntas-frecuentes-sobre-los-certificados-de-energias-limpias

First of all, the information that will be captured and registered in the platform needs to be clearly defined, as well as who will have access to it. An example of relevant information to capture is the source of the energy, to identify how the energy was generated and from which technology the electricity comes from. Then, it is important to define how the information will be captured into the platform, considering that if you introduce dirty data into the Blockchain you will obtain an untrustworthy result (garbage in – garbage out problem). Here IoT and smart meters can play an important role in capturing information from DER's. Afterwards, the CEL is assigned to the clean energy generators based on the amount of electricity produced. Once the CEL has been issued market players need to identify the counterparty to trade with them.

There are different public and private actors that are currently involved in the CEL market. The CRE has a key role since it is the market regulator, furthermore it is also responsible of CEL issuance. Before Blockchain could be implemented in the Mexican Energy Sector the CRE should approve the platform and necessary specifications for a Blockchain enabled marketplace. The CENACE will be responsible of reporting the energy generated by each player to the CRE to define the CEL that corresponds to each one, therefore they must have access to the data collection points that will be feeding data into the platform. CENACE also operates the Wholesale Electricity Market in which CEL are traded.

The private participants in the CEL market are the clean energy generators which receive CELs for every MW/h of clean energy generated, which are then sold to obligated parties. The players with the obligation to buy CELs are suppliers (including CFE), qualified users participating in the market, final users under self-supply schemes and parties with legacy interconnection contracts. An initial approach for introducing Blockchain within this process can be made among private participants through the creation of a small-scale voluntary market to provide sufficient information on the feasibility, main benefits and potential market impacts to CRE and CENACE. This could provide valuable information to the public sector for evaluating Blockchain as a tool to improve the current CEL market.

After identifying the stages of the process and the actors involved, an exercise was conducted to assess the pain points of the selected process. The pain point defined as the most relevant was the lack of transparency in available information to market participants. By having information transparency on how much renewable energy is produced, the location where it is produced and the growth-rate of distributed generation, market players will have increased market certainty that could increase investment allocations for the Mexican Energy Sector. In Mexico, transparency is also an issue for the TSO, since it doesn't have clear information on the growth and location of renewable energy plants and DER's; access to this information could facilitate decisions regarding the grid and its infrastructure.

Other relevant pain points mentioned are deficient origin traceability (it is difficult to verify the generation source and consumers can't prove the origin of the energy they are buying), bureaucratic processes including reporting and verifications, and a lack of standardization at a global level. Luis Guillermo Pineda from the CRE mentioned that the current process for monitoring and accounting CEL transactions is very complex and carried out through somewhat manual activities. The market requires trustworthy information on the amount of available CELs, therefore constant information update is crucial. This increases the risk of having errors in the information registry and results in a time-consuming activity that could be optimized with Blockchain.

Graph 4.12 – Decentralized CEL Marketplace Use Case

Decentralized CEL Marketplace

Use Case Description

A Blockchain enabled platform in which information regarding clean energy certificates is introduced, such as time, source, location and generators to keep accountability of the specifications regarding clean energy generation in Mexico. Market players would be able to trade CELs with counterparties through the platform.

Benefits

- Having a standard framework for all actors to base their decisions
- Increase trust and reduce risk from the buyer side by having access to transparent information
- Access to data form multiple participants in the chain value
- Access to a decentralized marketplace for a wide pool of participants
- Risk mitigation for emerging markets by leveling the playing field to provide incentives for capital allocation

Challenges

- Adherence with regional and local fiscal, financial and regulatory frameworks in different countries
- Ensure correct registry of data when integrating devices (Garbage in - garbage out problem)
- Cybersecurity and information privacy concerns (e.g. GDRP compliance)
- Solving the Blockchain "Trilema" for industry grade solutions: Security, Speed and Decentralization
- Establishing frameworks for democratizing and incentivizing the entry of new participants

Energy Partnership, 2020

The selected use case therefore seeks to solve these pain points within the CEL market current state. Blockchain can be used to create a decentralized CEL marketplace with a standardized framework for all network participants to trade renewable energy certificates. High impact shown in graph 4.10 is due to the transparency and accountability it can provide for this type of markets, increasing trust while reducing risks among counterparties. However, it has lower feasibility than the other two selected use cases on account of existing regulations, acceptance to adhere to a standardized framework and coordination efforts to set up this marketplace. This use case belongs to the Market Decentralization category since it will enable a decentralized ecosystem for industry players to engage in a marketplace that provides a reliable and efficient mechanism for executing transactions. However, it also has some key characteristics from Transparency & Traceability business models.

The proposed Blockchain platform enhances information transparency by giving permissioned access and visibility of specific parts of the process to relevant parties involved. It can reduce bureaucratic issues since data sharing and verification between the involved parties would no longer be necessary. The distributed trust ecosystem enabled by Blockchain eliminates the need for a third party to verify every transaction, resulting in time and cost reductions and making the market much more accessible for small-scale participants. If the CEL market was to be standardized at a global level, international players would also be able to buy CEL and achieve value in their own countries.

Furthermore, having a standardized CEL framework for all industry players (along with the low transaction costs the platform offers) could enable a voluntary marketplace where individuals or small businesses can trade certificates or keep them as a proof of their clean energy consumption. This voluntary market could help increase the demand for CEL and raise their prices, thus increasing the attractiveness of renewable energy investments. One benefit directed specifically towards the CRE is that, if CELs are traded in a Blockchain platform where every transaction is immutable and traceable it will enable the regulator to have a near real-time automated match of organizations who have already met their CEL obligations, saving significant time and resources. The CRE could also charge fees to participants not complying with their sustainability obligations in an automated way through the use of smart contracts and available information registered on the Blockchain.

As mentioned before, the selected solution was oriented towards the Mexican CEL marketplace. Although the decentralized CEL marketplace was selected among various proposed use cases, there are other Blockchain applications that are worth mentioning for this process. One example is an automated payment and matchmaking platform for CEL trading in which the marketplace does not work merely as a trading platform, but also to help identify and coordinate potential sellers and buyers through smart contracts. Another complementary solution is a traceability tool that contains relevant market information regarding energy generation and consumption, where they key driver is not to offer tradable certificates, but rather offer transparency and traceability of energy attributes to organizations. Lastly, there is the possibility of creating digital assets to certify ownership of real-life resources beyond green energy certificates; some examples are carbon emissions, energy efficiency certificates and tokenized DER infrastructure.

There are some challenges that need to be considered when analyzing a potential decentralized CEL Market through a Blockchain platform. One of the most common concerns is data privacy. Since information captured in the platform will be immutable it is important to define which information will be introduced and who will have access to it, while making sure to remain compliant with international standards such as the EU's GDPR framework. Another challenge is setting up the required infrastructure in order to ensure correct data registry and validation to guarantee trust among the network. Lastly there is a coordination problem for incentivizing industry players to participate in this market, where a network effect challenge may arise from a lack of participants or initial critical mass to make the platform operable.
For this use case to work regulators and policy makers must be on board, which may represent a significant challenge as well. As pointed out by several expert in the workshop, energy ministries usually need examples of how this use case is being applied in the real world, they need to see it is already operating to fully trust it. Authorities seek to have real life examples and successful cases given that there is a high risk for users, who could be affected if something goes wrong. Nevertheless, marketplaces similar to the CEL in Mexico is one of the most developed use cases around the world and there are many organizations that have already developed solutions that supports its feasibility. One example is the Energy Web Foundation through their SDK EW Origin.

Before implementing Blockchain solutions it is recommended to test a Minimum Viable Ecosystem to see if participants truly share pain points that could be addressed through a large-scale solution. It also refers to the minimum number of participants interacting in the platform for it to make sense, since Blockchain's benefits are much more relevant when there are numerous players interacting with each other.

Data and information accountability for contract enforcement

Contract management was also considered a key current process in which relevant pain points could be addressed through a Blockchain platform. It was considered a process with high Blockchain potential since current centralized systems lack contract enforcement and control. A distributed platform could help manage contracts through a solution where certain processes could be streamlined and third party interactions are made more efficient. For example, when signing PPA contracts it is necessary to present a guarantee to reduce the counterparty risk, the platform could facilitate the process of presenting, verifying and authorizing financial collaterals.

By making information across the market transparent, players could be more certain regarding payments and risks involved in contractual agreements, which would consequently increase market attractiveness. Having contractual information registered on a Blockchain platform opens a wide range of opportunities to streamline processes and enhance data transparency. It is also feasible since it doesn't necessarily need an authority to be on board, private players are the ones negotiating PPA's and the solution would benefit them directly. The potential of Blockchain for contracts and PPA management has already been tested in international companies.

Some organizations such as WePower have simplified the PPA process through a Blockchain platform and demonstrated that value can be created by introducing contract information.

Graph 4.13 - Contract Management Current-State Process Flow

1. Definition of contractual agreements and proposal signature by the counterparties involved
2. Definition and acceptance of the financial guarantee of collateral attached to the contract
3. Contract registry and validation with corresponding regulators and authorities (both national and local levels)
4. Settlement of the contract conditions between counterparties (e.g. fees, rates, dates, penalizations).
5. Invoice balance calculations and conciliations between counterparties

Energy Partnership, 2020

The first step is to define the contractual agreement and obtain the counterparty signatures. This implies that the identification and selection of potential buyers/sellers will remain under the current system, since there are no matchmaking platforms or representative private bids. After selecting the counterparty for the PPA, negotiations between the parties begin to set the price for energy, non-compliance fees, collateral definition and acceptance, general terms, amount of energy and ancillary products. Authorities need to be notified about the intention of signing a new contract, in the case of Mexico it is required to notify CENACE and CFE. Afterwards conditions are agreed upon and the contract is signed. Once the PPA is signed by both parties and the generator is selling energy to the final consumer, invoice balances and conciliations are required.

The main actors involved in this process are the energy buyers and sellers, since they are the ones that are trading goods. Sellers need to have an energy generator plant, qualified supplier or marketer permit from the CRE for them to be legally allowed to sell energy. On the other hand, buyers need to be constituted as qualified users for them to be able to buy energy from private generators. It is probable that energy buyers and sellers would have to develop this solution independently due to the fact that they are the players that will receive its benefits. CENACE is in charge of defining the price at generation and consumption nodes and of making the settlement for the value of energy traded. Another organization that is involved is CFE, they measure the energy that is injected and extracted from the grid. Even though these entities are involved in the signing of PPAs, they are not involved in all the contractual specifications, they would only provide specific data points that can be leveraged in the proposed solution.

There are currently several pain points for contract management in the sector. One of the main concerns identified in the workshops is regarding data. There are two main factors to consider when data is introduced to the Blockchain. The first is to figure out a way to guarantee that trustworthy information will be registered and second is how to maintain data security and end-to-end cybersecurity. Blockchain could help overcome security concerns, nevertheless, the validity of the information needs to be secured before introducing information to the Blockchain through data collection and infrastructure management. Other mentioned pain points include the lack of visibility of information and processes from parties involved. One example are the costs associated with transmission or market operator fees, in which market players don't have full visibility on how the fee is being calculated.

Moreover, low contract compliance was also mentioned, which is a pain point that Blockchain could solve through the implementation of smart contracts on specific contractual conditions that can be programmed. Additionally, contracts can sometimes involve long and bureaucratic processes that can take several weeks or even months, representing high negotiation costs. Blockchain could streamline some processes by having information accountability on a contract and smart contracts as an additional feature to enforce them. The enforcement of agreed terms can help give certainty to players for solving this specific pain point. Blockchain could also act as an intermediary to assure that the contractual terms are being met, this will provide trust to market participants and risks will be reduced.

There are many use cases in which Blockchain could be implemented in PPAs, however the identified pain points related to contract enforcement can be solved through the second selected use case: Data and information accountability for contract enforcement. This candidate has a more balanced feasibility-impact evaluation, where an increase in efficiency for contract management, communication enhancement between industry players and increased accountability by counterparties supports potential industry impacts. Meanwhile, setting up the necessary infrastructure for data collection, interoperability with existing legacy systems and maintaining compliance with current regulatory frameworks represent restrictions which lower the use case feasibility.

Graph 4.14 – Contract Enforcement Use Case

Data and Information Accountability for Contract Enforcement

Use Case Description

Contractual information can be introduced into the Blockchain to have accountability of transactions involved and use smart contracts to enforce certain payments. Additional features include PPA secondary market and settlements.

Benefits

- Streamline the process increasing efficency while reducing costs associated to collaterals
- Improve data access that could reduce reconciliations and manual process
- Enhance communication among industry players through better data sharing, resulting in cost and time savings
- Reduces friction for buyers/consumers to switch energy providers and increases competition in the market
- Secondary markets provide liquidity to market participants and reduces risk

Challenges

- Convince market players to join a network that enables the use case (test the minimum viable ecosystem)
- Developing the business case and identifying key indicators such as the return on investment to involve stakeholders
- Data standarization among all market players
- Compliance with current regulatory frameworks and required data points to enable the proposed solution

Energy Partnership, 2020

This use case implies that information on the PPA will be introduced to a Blockchain platform and smart contracts will self-enforce certain agreements within the contract. It could support transaction verification and provide a trustworthy source of information for the counterparties. One of the main tangible benefits for PPAs are the settlements, which require multiple parties sharing and comparing data and then calculating the final invoice. CFE measures the electricity produced and consumed and then shares it to CENACE; CENACE takes this information and considers the nodal prices from each point to make settlements and finally shares the final invoice to the consumer. This process is done every hour for each active PPA contract in the country. By including this information on a Blockchain, it won't be necessary to share it repeatedly and every player involved could have access to it. This would allow CENACE to have near real-time measurement information from CFE, and the parties that signed the PPA could see their consumption or generation in real time, all validated by participants through the

Blockchain. Settlements could therefore be automated through smart contracts to save time and reduce costs. Besides invoice settlements there are other ancillary products that market players need to access to comply with industry regulations. Some of these products include Capacity Balance and CELs. The CENACE needs to have transparency of these ancillary products to know who has already complied with their obligations. If information regarding the price and quantity of energy is already being introduced into the Blockchain, it could bring additional benefits to include information regarding ancillary products. By including this information, the reporting of ancillary products obtained could be streamlined, making it easier for regulators to verify who has complied with their obligations.

By having the PPA terms agreed upon on a Blockchain certain clauses could also be enforced. One example could be the payment of non-compliance fees. There are certain fees for failing to comply with contractual terms such as not delivering the energy that the seller committed to, or the buyer not paying for the energy it received. These fees could be automatically charged with smart contracts (excluding the need of lawyers and legal disputes) when the necessary information can be obtained from the Blockchain. Juan Roberto Lozano, Head of International and Governmental Affairs at CENACE, pointed out that similar smart contract functionalities could likely be leveraged for certain specific uses, including the enforcement of the grid code, helping to assure that every market player connected to the grid complies with safety and technical requirements.

Another contractual item that could be automated and endowed with transparency are the regulated costs mentioned above, which include transmission and distribution fees and CENACE's fees. Currently, market players can't verify how this fee is determined. If this information was included on the Blockchain it would provide benefits to market players as well as regulators. Market players will benefit by having full transparency regarding how the fee was calculated, providing trust to the system. Regulators will benefit by having a record of all the payments that have been done and as an extra layer, payments could even be automated.

Other related use cases with potential were also proposed, one of them in which companies are showing interest is the need to demonstrate their renewable energy consumption. At this time, it is difficult for companies to prove this information since there is no legal document that accredits the purchase of clean energy. Blockchain could tokenize these certifications when clean energy is generated, allowing them to be transferred to companies to prove the source of the energy they are consuming, granting accountability for sustainability goals and mitigating climate change related risks.

Mexico still has a traditional model in which consumers seek private generators to negotiate a PPA, but in other countries there are certain platforms that help match generators with consumers according to needs and characteristics of each case. A decentralized marketplace for PPAs would facilitate buyers/sellers to find each other, which could incentivize the market through a more efficient and automated process to match transaction counterparties. This marketplace could decrease entry barriers for small scale consumers and allow them to access these models. PPAs could be tokenized through a Blockchain in which many small-scale consumers could buy energy and have a token for the rights or obligations that correspond to each one. Tokenizing the fractions of a PPA also enables a secondary market in which PPAs could be traded. This provides market players with certainty by enabling small energy consumers who own a PPA to sell it to a third party in case of bankruptcy, this way the generator will still have a buyer and the consumer could get some liquidity through the transaction. Signing a PPA with a small-scale consumer can represent risks for the generator and excessive costs for the energy sold, by signing PPAs with multiple small-scale consumers the risk is distributed, and the secondary market gives certainty to the transactions agreed.

One of the main challenges for implementing this contract management platform is to onboard a sufficient number of participants interested to develop and join this platform for it to add value. Blockchain does not make sense if there are only a few participants interacting in the platform. This is the reason why it's important to evaluate a minimum viable ecosystem before implementing the use case. Another relevant challenge is the creation, introduction and processing of data within the platform since information needs to be accurate and standardized. The Blockchain will need to have access to each piece of information from a contract and the best way to achieve this is by setting a standardized format in which the information is introduced. It is important to consider that the data introduced, and the standardized framework would have to comply with applicable regulations.

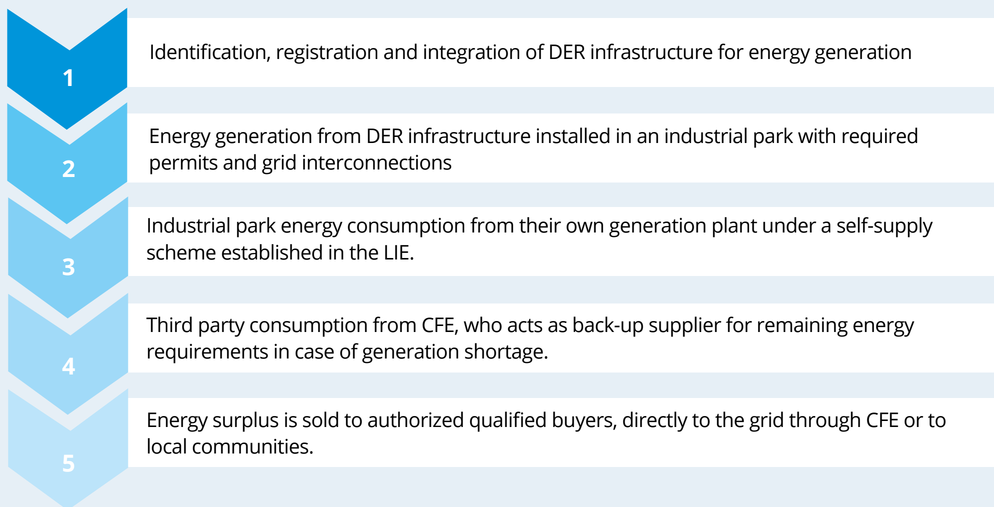
Decentralized retail market for industrial parks to sell excess energy

The last selected current state process was DER integration and optimization for industrial off-grid applications. This process was considered to be relevant for evaluating potential Blockchain applications due to the large volumes of data incoming from multiple DER infrastructure installed in industrial parks for self-supply. Another process that also obtained a good evaluation by experts was the integration of DER infrastructure into the grid. In this case, a Blockchain platform could allow the system operator to maximize the potential of the increasing amount of DER's in the grid by identifying and registering them, enabling applications that leverage the data they input into the registry.

Both processes are highly related, however, integration of DERs from industrial parks resulted as the selected process flow. This was mainly due to its focus on a specific part of the value chain, making it a much more feasible process for an initial exploration phase with Blockchain technology. Additionally, it also serves as a small-scale testing environment for the future integration of a wider array of DER infrastructure, which can be scaled to additional devices outside of industrial parks, such as PV cells, wind turbines, EV's, smart meters, IoT devices and storage facilities. Therefore, feasibility was prioritized over impact to analyze potential use cases with less implementation constraints in the local market.

The selected process was mapped out into 5 general steps in order to evaluate opportunities where Blockchain becomes relevant by identifying the main actors involved, relevant stakeholders, industry pain points, potential benefits and additional strategic considerations. Graph 4.15 shows a high-level perspective of how DER integration and optimization is carried out:

Graph 4.15 - Industrial Off-Grid Applications Current-State Process Flow



Energy Partnership, 2020

The first step is to identify the DER infrastructure that must be integrated into the grid in order to obtain the required generation permits and establish grid interconnections. Afterwards the generation plant begins to produce energy which can be used for multiple ends. The main purpose for which industrial parks install this type of infrastructure is for self-supply. However, if the generation plant has a permit from CRE to participate in the MEM they can sell their excess energy to a third party, which must be an authorized qualified user or qualified service provider (e.g. adjacent factories or another industrial park entirely). Finally, if excess energy is not sold to a qualified third party, the generator can sell the excess energy directly to the grid. It is also worth mentioning that energy surplus could also be sold to local communities; although there is no current regulation for community generation, there are plans to incorporate this model into Mexican legislation, making it an interesting opportunity area to evaluate.

There are several actors involved in this process from both the public and private sector. From the public side, CFE has rights reserved by the State for energy distribution and transmission, making them a critical actor for two reasons. First, when selling energy to the grid it is sold directly to CFE. Secondly, even when selling the energy to a private qualified user CFE still interacts in the operation by charging transmission and distribution fees and by measuring the energy generated and consumed by the involved parties. Additionally, CFE can also serve as a back-up energy supplier if the industrial park requires additional energy. CENACE also has an important role, as it supports transactions between generators and consumers in the MEM and provides grid stability, therefore they become relevant for conducting DER interconnections with the grid and for monitoring DER infrastructure at a national level. Lastly, CRE is responsible of regulating the sector, therefore required permits for acting as a generator and/or a qualified user must be authorized by this Institution.

Relevant actors are also found in the private sector. The most important ones are industrial parks, along with the factories and plants that conform it, as the analyzed process is focused on them and their DER infrastructure which can be integrated and optimized for off-grid applications. Potential use cases revolve around generation plants that aim to supply power to an entire industrial park, and possibly to other third parties like local communities. This is why players such as qualified users and service providers must also be considered, since they can also become part of this network, allowing them to buy available energy surplus from renewable sources at competitive rates. More critical actors will emerge as the regulatory framework advances towards incorporating community distributed generation, such as energy communities/cooperatives and renewable energy farms. Lastly external players must also be considered, more specifically infrastructure suppliers, technicians and maintenance providers, financial institutions and development banks.

Experts pointed out many industry pain points specific to the analyzed process, where the most issues where found within the Energy & Services and Social, Cultural & Educational pain point categories. The first, and perhaps most critical concern expressed during the workshop, was related to the energy quality and reliability. Generation plants installed in industrial parks are more commonly equipped with DER infrastructure that produces energy from renewable sources, meaning that they are subject to variable generation due to fluctuating natural factors (more specifically wind and solar resources). Consequently, energy quality and reliability represent a challenge for participating parties. Another problem the industry is facing is the price and quality of services provided compared to the default supplier.

Access to human capital is also a significant pain point. There is a lack of knowledge and required technical capabilities in the market, making it significantly difficult to adopt innovative business models and implement new technologies within current processes. In fact, this was a paint point identified in all selected processes, but it was considered much more critical in this case due to the higher involvement and development required from interacting parties. Other identified issues include regulatory, bureaucratic and red tape constraints, which can hinder permit processes, elevate set-up costs and delay investments in attractive projects.

Graph 4.14 – Decentralized Retail Market for Industrial Parks Use Case

Decentralized Retail Market for Industrial Parks

Use Case Description

A wholesale energy marketplace for players within an industrial park to buy and sell energy, using a distributed platform to enable B2B transactions and share information in an efficient, transparent and secure way.

Benefits

- Attractive to policy makers since it is a feasible use case with high social impact
- Attractive to private organizations due to feasibility, thus increasing willingness to invest
- Efficiency of managing multiple contracts among participants
- Additional revenues from DER´s, which can incentivize organizations to reach sustainability goals
- Facilitates creation of "plug and play" applications for DER devices that input data into the registry

Challenges

- Privacy concerns regardind th informations produced by connectes devices
- Regulatory and pricing issues may complicate the business case, lowering incentives for potential participants
- Regulatory certainty in the market for implementing this type of innovative business models
- Demonstrations of a minimun viable ecosystem of participants willing to develop the solutions
- DER registry is prerequisite for decentralized marketplace participants

Energy Partnership, 2020

Considering these elements, experts proposed several potential Blockchain use cases to be considered for the selected process. A decentralized retail market for industrial parks to sell excess energy obtained the highest evaluation. It also scored with the highest feasibility among the three selected use cases, but conversely showed lowest impact. The main impacts are related to new revenue streams from DER infrastructure, creation of incentives for organizations to invest in DERs and reach their sustainability goals and its attractiveness to policymakers due to potential social impacts. High feasibility can be seen as it is a use case that can be deployed among private organizations. This can facilitate the setup of required infrastructure and DER registry, as well as the overall coordination for a minimum viable ecosystem to test the use case. Additionally, existing regulations allow for interaction among authorized generators and qualified users, providing a clear reference framework for developing a technological solution of this nature.

Blockchain can enable a decentralized market where participants who produce their own energy through DER's can sell energy directly to other ecosystem players. Industrial Parks represent a great environment where factories and manufacturing plants have high incentives to consume energy from a private generation plants. Some examples include: energy consumption from renewable sources in order to reach sustainability goals, access to locally produced energy, increased quality in utilities and services provided, higher flexibility when selecting their energy suppliers and more competitive prices. Furthermore, its high feasibility also makes it an attractive use case for private organizations, thus increasing their willingness to invest.

Having a platform where DERs can directly interact with high-demand energy consumers can provide network participants several benefits to improve the current system. A decentralized wholesale market between authorized renewable generation plants and qualified users is a clear example. Industrial parks generally install this type of infrastructure for self-supply purposes, however this use case would allow to generate new revenue streams by selling energy to other network participants. Therefore, this application can be categorized as a Market Decentralization with functionalities mostly related to Wholesale/OTC trading, although in future development stages of the use case it could also have high Micro/Community grid capabilities.

Another interesting opportunity that could emerge from this use case is the creation of "plug and play" applications by leveraging valuable data that DER devices are constantly generating. Solutions of this sort would connect devices to a Blockchain platform, continuously registering relevant information that can be used by market participants to add value along additional processes of the value chain. One example of decentralized applications aligned to the selected use case are incentive mechanisms for industrial parks to consume locally produced green energy, some possibilities are: an immutable audit trial for stakeholders to evaluate sustainability goals and accomplishments, tax incentives for participants who consume from these DERs, distributed energy allocation for DER owned by multiple parties and automated payments and settlements for wholesale energy transactions.

The main challenges this use case presents are related to privacy concerns. Industrial parks and its participants may not feel comfortable having fully transparent and open information regarding their energy capabilities and consumption patterns. A private Blockchain may become a more attractive option for this type of use case to avoid issues of this sort. Another challenge is regulatory certainty, given that stakeholders will seek feasible use cases from both a technical and legal perspective for long-term investments. Lastly, it is critical to ensure a minimum viable ecosystem where energy buyers and sellers would be willing to participate in; the use case will make no sense if either of the counterparties aren't interested in participating.

The selected use case is highly related to other identified applications shown in Graph 4.10. This is the case for industrial parks acting as community generators, where experts proposed that generation plants installed within industrial parks can provide energy not only to its factories, plants and businesses, but also to local nearby communities. This could provide benefits such as lower prices and increased energy quality and reliability for communities, while also generating social impact by incentivizing energy consumption from local green sources.

Another related use case is community generation through microgrids. A similar idea to the previously mentioned use case is followed, only here energy is not supplied by a privately owned generation plant, but rather by energy communities or cooperatives that function within a microgid. In this case the logic of the process flow is inversed, now it is the community who will act as a generator through shared renewable energy farms as a means to self-supply themselves, and excess energy can be sold to nearby industrial parks or separate factories and plants. Both of the associated use cases show a higher impact due to the positive social and sustainability effects it can offer. However, they were evaluated with lower feasibility due to the lack of a regulatory framework for this type of models, infrastructure set-up costs and high entry barriers in the market.

4.8 Main impacts and changes for the sector

As this chapter has exemplified through many international use cases and potential opportunities for the Mexican market, Blockchain has the potential to have great impacts in the Energy Sector and generate significant changes in the way the industry currently operates. The main impacts can be seen in the sector's three main trends: Decentralization, Digitalization and Decarbonization.

Decentralization

Blockchain's intrinsic nature is to enable decentralized models throughout a wide arrange of industries, and the Energy Sector is no exception. This is achieved by offering an alternative trust mechanism in a distributed ecosystem, enhancing interactions among semi-trusted parties and reducing the need to rely on a trusted third party as an intermediary. As seen in the three selected use cases, and in most of the examples reviewed, proposed solutions aim to increase transparency and traceability in processes that are highly centralized today, making them significantly more efficient, less dependent on third party interaction and highly trustworthy through a distributed ecosystem. Furthermore, Blockchain enables a highly efficient way to integrate the increasing amount of DER's and connected devices to the grid, which will be essential in the development of an increasingly more complex and decentralized energy system.

Digitalization

Blockchain offers network participants an immediate and remote access to a distributed ledger of registered information. This digital database creates a traceable and auditable trail of processes recorded on the Blockchain, which due to its immutability and transparency is also known as "the internet of truth" or "single source of truth". This enables digitally native business and operative models by offering a distributed platform where all network participants can initiate, validate or authorize a wide array of interactions for a specific process. This idea is further reinforced when incorporating smart contract functionalities into a process, allowing automation through programmed self-enforcement rules. These properties make Blockchain a key technology to consider by organizations in the Energy Sector for their digital transformation strategies.

Decarbonization

Characteristics such as transparency, traceability and immutability can also have a positive impact in the Energy Transition towards renewable energies and the overall achievement of decarbonization goals. The decentralized CEL / REC marketplace is the best example of how Blockchain can directly influence this field by providing a more efficient, transparent and trustable mechanism for certifying energy attributes that can be transacted among network participants. Other use cases also have an impact in decarbonization by incentivizing investments in renewable energy sources, facilitating the adoption of DERs, increasing green energy consumption and democratizing market participation for small-scale players. Furthermore, social impact includes cost reductions for final users, increased market competition and creation of digital channels, however, transition to clean energy remains as the most important potential impact of all.

Impacts across the three main trends means the industry will also have to face transformations in order to successfully adopt Blockchain solutions. The first significant change is close industry coordination to solve shared pains, meaning that competitors will need to cooperate towards a common goal. This concept is known as "Coopetition", and it represents one of the major paradigm changes that Blockchain brings. Key aspects to consider in this transition phase is the consolidation of a Blockchain industry consortium, identification of industry priorities, establishment of a governance structure, definition of a protocol and investment distribution among interested parties. Clear communication and right timing are essential to adopt these changes.

The second change to have in mind is related to regulatory frameworks and industry standards. Existing regulations today did not consider new business models based on digital technologies such as Blockchain, therefore they are not prepared to adopt this type of solutions into the market. Similar to the financial sector, Blockchain is forcing regulators to re-examine the current regulatory framework in an effort to incentivize innovations and the adoption of new technologies while safeguarding the industry's stability by mitigating significant risks that could have a negative impact in the market. Relevant regulations are not limited to those specific to the Energy Sector, other important regulations and standards include data privacy, cybersecurity, digital assets, AML/CTF and securitization.

The final change that will be necessary for a full Blockchain implementation is infrastructure modernization. Available infrastructure today is not prepared to incorporate digital technologies in large scales. Likewise, predominant systems used by industry participants are outdated and can represent a barrier for technological adoption. Therefore, the entire system requires a gradual renovation to improve data collection capabilities, enhance monitoring activities, boost data analysis and streamline manual processes.

Modernization should first be focused on specific critical points of the grid that can be used t o test technological innovations. This will allow users to fully understand how system integration will be triggered on large-scale projects and to set technological standards that guarantee interoperability with existing predominant industry systems.

4.9 Risks and mitigation strategies

There are several risks to have in mind while conside-ring the implementation of a Blockchain use case in the Energy Sector. It is important to promptly identify said risks and develop a strategy to mitigate or minimize them. In this section several risks will be analyzed, and some mitigation actions will be provided.

In order to mitigate risks associated to Blockchain it is important to fully understand how the technology works under each circumstance and use case where it is implemented. Additionally, individuals within an orga-nization will have to develop certain habits and culture to achieve this. For example, safeguarding a private key is a vulnerable area since it serves as a mechanism to access information on the Blockchain. If a private key is lost, all the assets within the Blockchain platform could be compromised if it falls into the wrong hands, or even completely lost if it cannot be recovered. There is no central organization to turn to for reestablishing a private key, unlike other password mechanisms people are more familiar with today.

Initially, there are many risks associated with the tech-nology itself. Even though Blockchain has been tested with numerous use cases at a global level, it is probable that new risks will continue to emerge. One comparable example is cloud technology, where in the beginning it was widely used and trusted by individuals to upload documents and pictures. However, hackers' soon made vulnerabilities of this system evident by extracting sensitive information that had been uploaded, raising awareness regarding cybersecurity and privacy concerns among its users. The key takeaway is that major risks and vulnerabilities of new technologies are generally uncovered once mass adoption takes place, due to the fact that incentives for exploiting them are maximized at this point.

Another Blockchain risk is found in the use of smart contracts. If programmed incorrectly, or without con-sidering certain outcomes, self-enforcement rules may fail to execute, in which case both counterparties may be negatively affected in the final outcome. It is recom-mended to only use smart contracts when conditions can be easily predefined and in situations with predictable outcomes and a low probability of dispute for a success-fully execution.

There are also specific risks in a public Blockchain, where decisions are made by consensus mechanisms in which a majority of network participants have to validate and authorize all transactions. Risks associated to this distributed trust mechanism arise if the network beco-mes highly concentrated in a group of stakeholders that could manipulate the outcome of a Blockchain registry in order to benefit themselves at the expense of other participants. Other risks related to the consensus mecha-nism can come from unreliable network participants that engage in untruthful behaviors which can harm the ne-twork. Another challenge is related to the pseudo-anon-ymous interactions that characterize public Blockchains, making it difficult to identify harmful participants. There are many Blockchain protocols available that attempt to address these challenges in different ways; choosing a suitable platform for each use case is key to minimize risks associated to consensus.

The regulatory framework could also represent a risk. Regulations establish how technologies can be used and what business models are allowed within a certain space. Regulations are generally a step behind from innova-tion and new technologies, since regulators first need to understand and see how the technology works in real life use cases to define a framework accordingly. It can be complicated to mitigate regulatory actions as they suffer constant change, meaning that something currently permitted will not necessarily remain the same in the future, and vice versa. Close collaboration and communi-cation with regulators and authorities can help mitigate these risks. Their perspective will shape the decisions taken toward the implementation of disruptive techno-logies and new business models. The best-case scena-rio is for authorities to have an open collaboration and communication attitude with the private sector. In this scenario the private sector innovates while supervised by regulators, receiving constant feedback or concerns on the proposed business models.

One of the most common ways in which the regulator enables innovation and gets involved in the process is through the creation of regulatory sandboxes. A sandbox is a controlled and safe environment in which organi-zations can innovate by creating new business models that fall out of the current regulation. This model can

benefit the private initiative by providing a risk-free space in which they can innovate freely, and authorities can evaluate the outcome of proposed models to identify further risks that must be considered when adapting existing regulations. There is an alternative scenario in which authorities and the private sector don't collaborate with each other to innovate. In this case, as Michael Lebbon stated in an interview, it is recommended to innovate and design new business models under the current regulatory framework to avoid further legal issues.

Additional risks emerge during the implementation process. Stakeholders must first have a clear understanding of what the problem they are trying to solve is, and then define if Blockchain is a viable solution. Elizabeth Massey explains that it is crucial to identify the problems which a technology can help solve by categorizing them within in three broad types: problems that are known, those which are unknown and finally the unknown unknowns. The latter can be identified through pilots and testing phases. Pilots can also help pinpoint risks and challenges related to a new technology, help organizations define clear scaling strategies and to spot issues that might arise when replicating international successful projects in a local context.

Additionally, there are different types of Blockchains with specific functionalities and risks that must be assessed. It is important to select the type of Blockchain that best adapts to the requirements of the proposed business model. Next, a quantitative evaluation of the expected added value will provide information on new revenue streams, cost reductions, process streamlining, access to new markets, initial investments and other associated costs. This task can be quite complicated due to a lack of successful implementations to benchmark and multiple parties involved in the development of the solution. However, it is critical to have these points clearly outline to avoid the risk of disbursing significant investments in non-feasible solutions.

Even when a Blockchain solution makes sense from a business and technological point of view, it is important to assure a correct deployment. Talent is a key factor for this step, unfortunately available expertise and capabilities in Mexico regarding Blockchain implementation are still scarce. Furthermore, this process is continuous, and individuals involved will need constant training to be up to date with technologic advancements. There must also be a designated team to oversee the solution's ongoing performance once it has already been implemented to assure that the technology is being used as it should and to identify flaws in the process. As Fernando Vera, CEO of Lumit, emphasized, those who are at the executive level do not fully understand that a technological change occurs over time. Returns may not be shown in the first 2 years, causing most projects to end before tangible results can be evaluated. Another risk is that digital technologies are not deployed correctly, this process must be continuous when working with digital technologies due to constant developments and innovations.

Moreover, there are risks associated specifically to implementations in the energy industry since it is a strategic sector that has a direct impact on businesses and individuals. Use cases related to accountability of energy generation/consumption or grid management will have higher operative risks than those that seek to provide transparency and traceability to energy attributes. The main reason is that a flaw in the first examples could have serious negative consequences such as grid instability, blackouts or infrastructure damages.

To avoid risks of this sort it is recommendable to first develop small-scale pilots for proving the use case before scaling it to a full market grade solution. Even though a pilot in a small-scale environment will help pinpoint several risks and challenges from a Blockchain implementation, it is not a guarantee that every risk will be identified in said tests.

Data privacy and cybersecurity also represents a risk if not handled correctly. As the world is becoming more digitalized there is a higher threat from hackers trying to attack digital systems. This is a highly relevant concern for the Energy Sector since an attack to the electricity system could have negative affects across an entire country. One example is the attack on the Ukrainian power grid in December of 2015, when a regional electricity distribution company reported service outages to customers. The outages were due to a third party illegal entry into the company's computer and SCADA systems. Shortly after the attack, Ukrainian government officials claimed that outages were caused by cyber-attack.

There have also been cyber-attacks in Mexico; in 2019 Pemex's systems were hacked, disabling the company to conduct transactions and generating malfunctions on 5% of personal computers.

Blockchain's characteristics do not provide an impenetrable panacea to all cyber ills. Instead, as with other technologies, Blockchain implementations must include robust system and network cybersecurity controls, due diligence and procedures. Many of Blockchain's attributes such immutability, decentralization and traceability help minimize the risk of cyber-attacks, nevertheless,

perpetrators are always seeking new methods to attack a system and it is important for organizations to implement controls in order to protect their organizations from external threats. There are three elements to keep in mind when referring to data concerns.

The first one is confidentiality, which refers to sensitive information that cannot be disclosed to unauthorized individuals or entities. Ensuring that only relevant and authorized parties have access to the correct and appropriate data is a common concern for organizations considering the use of Blockchain today. Therefore, protecting Blockchain's network access is fundamental in securing data access (particularly in the case of a private Blockchain).

Secondly is data integrity, denoting the need to maintain and assure that data is accurate, consistent and trustworthy over its entire life-cycle. This is a critical aspect to the design, implementation and usage of any system which stores, processes, or retrieves data. Some of Blockchain's characteristics such as immutability and traceability help organizations maintain data integrity. The real challenge for Blockchain is to guarantee that data introduced is reliable, since it can't be modified afterwards. The systems that introduce data to the distributed ledger need to be trustable and secure. Even if a Blockchain is highly secure, the systems that introduce information can also be corrupted, hence, it is important to have cybersecurity parameters in the systems that input data as well.

The last factor is availability, meaning that users must be guaranteed with a reliable access to information in the Blockchain. Cyber-attacks attempting to impact the availability of technology services continue to increase, seeking to make a network resource unavailable to its intended users by temporarily or indefinitely disrupting services. The decentralized nature and peer-to-peer characteristics of the technology make it harder to disrupt than conventional distributed application architectures (such as client-server). Even if a node is taken down data is still accessible via other nodes within the distributed network. Blockchain is a relatively safe tech-

nology regarding availability, nonetheless, it can also be subject to these attacks, and as such, adequate protection measures are still necessary, both at the network and application level.

There are many risks behind the implementation of new technologies, nevertheless there is also a risk involved when opting to not implement them. We have seen numerous cases of companies that didn't digitalize or adopt new technologies due to fear, uncertainty or focusing on other business priorities. In many occasions these companies lost market relevance or even disappeared from the market. Companies that anticipate the adoption of new technologies such as Blockchain may benefit from first mover advantages gained from experience and innovation, however they will also face significant risks and will have to embrace a learning process.

Digitalization is becoming more of a requirement every day in the Energy Sector. The growing number of participants and devices continues to increase the complexity of the system and its need to adopt new technologies for the overall improvement of the industry.

Decentralization in the sector is making it harder for players to maintain an accurate track and accountability of everything that happens within the national electricity system, and Blockchain as a decentralized technology can help smoothen the path towards more market participants.

5. Considerations, Recommendations and Conclusions

5.1 Considerations

Trends in the Energy Sector will help make it become more efficient, sustainable and dynamic; however, they can also represent a challenge for industry leaders and stakeholders. Digitalization is not something that occurs on its own, efforts across the entire value chain are needed to obtain its benefits. Companies and organizations need to invest in research and development of new technologies to explore how they could add value to their operations. Moreover, it is a challenge to maintain attractive and competitive prices while also investing in new technologies and innovation due to the high presence of commodities in the industry. Nevertheless, energy companies need to see digitalization as a long-term investment and begin to test technological solutions that will make them more efficient, thus reducing operative costs and providing them with a competitive advantage.

In Mexico there is a risk averse culture for the adoption of new technologies, acting as followers in the market and waiting for solutions to first be to be proven in other countries before implementing them locally. Letting other countries experiment with Blockchain use cases will reduce risks and lower costs during experimentation and testing phases, since there will be a reference guideline for stakeholders to decide where investment allocations make most sense and what applications can provide the best results in the local market. There are also downsides in letting other countries carry out the research and development of new technologies, and they might even outweigh the benefits in the case of Blockchain. One example is failure to retain talent that is ready to develop Blockchain solutions, if no opportunities are available in their market, they are likely to search in other countries that have a more mature Blockchain ecosystem.

Blockchain is not a technology to be adopted and integrated by a single company to create value, it is actually a tool that requires close coordination and collaboration among numerous participants to create a distributed ecosystem for a solution to thrive. The countries and market players that take the first steps to explore and adopt this technology will be seen as a reference for Blockchain solutions, positioning themselves at the center of the ecosystem and allowing them to set their standards for future trends and use cases. In other words, players that act as followers will look for available market standards and use cases, while first movers will be the ones to impose them.

Similarly to the internet, Blockchain creates global ecosystems. Countries that adopt the technology in early stages will develop more knowledge and capabilities, thus obtaining a significant advantage to create new business models and solutions. Market players today are not only competing at a regional level, but also at a global scale, meaning that competitive advantages derived from Blockchain capabilities can position an organization across the globe and open access to new international markets and channels as well. Digitalization is a must to remain relevant in the Energy Sector today, and Blockchain is a strategic technology to consider throughout this process.

Challenges of digitalization are different for each type of market player. According to Kira Potowski, small and medium enterprises must first think about survivability issues, and then consider innovation and digitization. Most digitalization trends and cases are being developed in large, international companies that by mandate of their holding must digitize energy operations. Other players, such as generators and distributors, have not yet seen the implementation of digital technologies for monitoring and traceability processes. In summary, it is more attractive for large international companies to invest in digital technologies since they can leverage their scale economies to implement them in internal processes and test new business models throughout different activities of the value chain.

Other key aspects that market players will have to keep in mind is the need of industry collaboration and co-investments. Some stakeholders might be skeptical of this approach as it requires investing in solutions that could also benefit their competitors. However, a Blockchain platform must be seen as a tool that can benefit multiple industry participants by solving a common issue while increasing the market's value by creating new digital channels and reducing entry barriers for small-scale participants, thus being able to access new clients and revenue streams that were not available before. As Nikolaj Martyniuk pointed out, Blockchain solutions are still quite expensive, so it makes sense to implement them in a market were several retailers or providers are interested in co-investing to reduce costs and risks. Infrastructure is another important element to consider when talking about digitalization. David Ricardo Sol, data and industrial automation specialist at BASF, emphasized that when organizations talk about digitalization, they assume that the necessary infrastructure already exists to enable new technologies. The reality is that connections points are limited, and it is expensive to install new ones. It is essential to have an adequate infrastructure in place for the implementation of new technologies to be feasible, and requirements may vary from one technology to another (and even from one use case to another). In Mexico there is a lack of modernization in certain energy infrastructure. Such is the case for transmission and distribution lines, which were installed many years ago under a centralized system approach. Some of the nodes are already saturated, not allowing profitable interconnections for new projects.

The regulatory framework must also be examined at the moment of evaluating digital strategies within the sector. This aspect may pose a challenge for innovation since the energy industry is one of the most regulated sectors, and regulations are subject to change over time. Currently, the Mexican Energy Sector is undergoing several regulatory changes. It is important to understand the direction that the current administration is adopting for the sector in regulatory terms before implementing Blockchain solutions. Luis Guillermo Pineda, Commissioner of the CRE, expressed that the regulatory framework is changing, and market participants will have to adapt to it. The current framework will continue to change and new challenges and opportunities will arise from these modifications.

New regulations could also enable new business models. One example is a regulation for community generation that is currently being evaluated. The regulation has been already been approved by the CRE, nevertheless it is still being analyzed by CONAMER before it is published in the DOF and becomes official. This regulation will be the first step to enable peer-to-peer business models, where Blockchain could provide a decentralized market for energy trading. Use cases in which investments from regulators are needed seem unlikely under the current landscape. Government entities have to operate under an austerity policy without much available budget for investments in new technologies. Nevertheless, it is important to actively involve regulators when proposing potential Blockchain solution for the market.

Before implementing Blockchain, organizations need to evaluate their technological maturity to know if they are ready to adopt this technology. The first step is to identify the technological limitations that an organization has, as well as the limitations in terms of knowledge and internal capabilities. Talent is one of the main challenges when considering a Blockchain implementation; consulted experts repeatedly addressed the lack of talent regarding digitalization in the Energy Sector as a barrier, and even more so for the case of Blockchain capabilities. There is available talent to develop digital energy systems in Mexico, however the problem is that efforts are not integrated, and organizations act independently instead of collaborating throughout this complex process.
While evaluating technological maturity, organizations also need to analyze their current processes and how they are executed, what actors are involved, how data is captured and stored, what systems and APIs are being used and what regulations come into play (e.g. data privacy and cybersecurity). It is important to consider interoperability when considering implementing Blockchain since the platform will require access to information from legacy systems, devices, API's and other data sources that will feed the Blockchain.

Hereunder are additional key aspects to consider for each of the selected use cases from section 4.7:

Decentralized CEL Marketplace

CELs are an ancillary product that certain market players have the obligation to buy in order to comply with their sustainability goals. It is important to consider that the CEL market exists because Mexican regulatory bodies created a framework for them, clearly defining rules on how they work by the law. Conversely to energy, a good that is needed in the market and thus has a steady demand from users that consume electricity, CELs have their demand established by authorities. Therefore, changes in regulations can have significant impacts in the CEL market, and consequently in their prices.

There is currently a regulation on hold which could modify the CEL framework, stating that legacy plants that operated before 2014 will receive CELs for clean energy, while originally only plants built after 2014 could receive CELs. This could potentially create an unbalance in the market by substantially increasing supply, while maintaining demand in the same level. Since the price of

CELs are defined by supply-demand economics, this increase could result in a fall in prices which in turn would reduce incentives to invest in renewable energies.

CELs are highly regulated products in a highly regulated sector, which makes them extremely dependent on the regulatory framework. It is important to consider potential changes in regulations, priorities set by authorities within this space and the direction of the market in regulatory terms when analyzing opportunities for the CEL market with Blockchain technology.

Data and information accountability for contract enforcement

The PPA market has more independence than the CEL market in terms of regulations. They are bilateral agreements among private organizations to purchase a certain amount of energy during a certain period of time, providing more freedom as to how these agreements are carried out and executed. An important consideration is that a Blockchain platform for managing contracts such as PPAs will need the involvement and participation of multiple players for it to truly add value to the current system. Some functionalities within the use case such as the secondary marketplace, predefined enforcement rules and contractual settlements don't make much sense if there isn't a sufficient critical mass in the platform to enable a distributed ecosystem.

The main challenge lies behind convincing and coordinating all relevant players to join the proposed platform and for them to co-invest with the objective to solve a shared industry pain. For this to happen, the use case pitch and communication strategy is of great importance, it has to be oriented towards a business perspective instead of a technological one, focusing on the business model and its main benefits for stakeholders to gain interest in the solution.

Decentralized retail market for industrial parks

The Energy Sector is currently experiencing several regulatory modifications, it is important to understand the implications that these regulations may have in DER infrastructure. The government is currently evaluating the modification of certain regulations from the "Ley de la Industria Eléctrica" which could result in affectations to this use case and the development of DER infrastructure in general. Even though it is hard to tell what the regulatory framework will look like in a short, medium and long-term period, it is important to keep in mind that it will continue to suffer changes which could represent both opportunities and challenges for solutions of this nature.

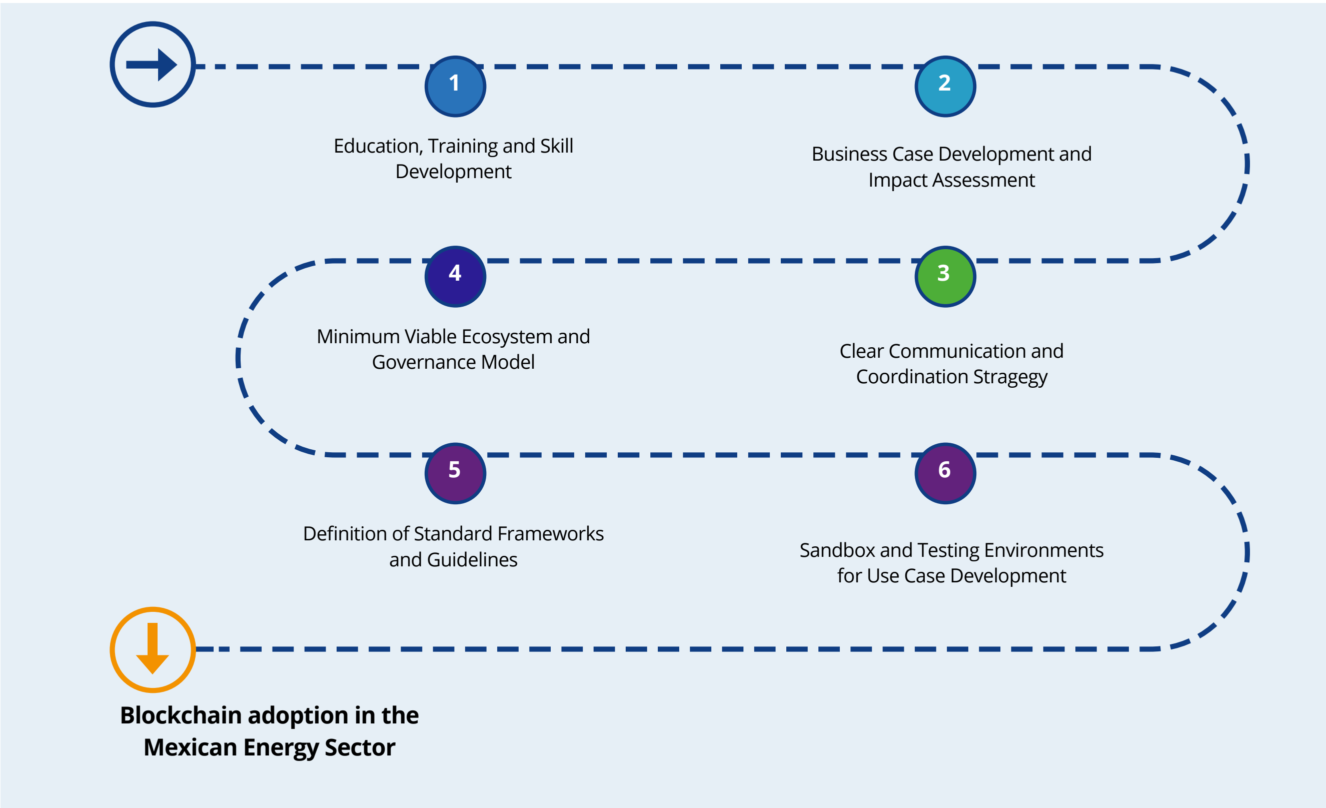
Other related use cases identified include industrial parks selling excess energy to local communities and communities and/or energy cooperatives acting as generators themselves to supply industrial parks. For this to be possible two things would have to happen. For the first case, the generator will have to be constituted as basic supplier and the community buying energy as a qualified user; the latter is currently a constraint for this use case. There are also some challenges regarding costs and prices since CFE basic supply highly subsidizes the energy tariffs. In the second scenario, the community or energy cooperative would have to be authorized to generate and sell energy to qualified users, which requires a regulatory framework which is not available yet. However, there are plans to include this model in Mexican regulations.

5.2 Recommendations

Industry-wide Blockchain adoption is an overwhelming task, with many factors to consider when building a strategy. Having various parties involved requires a multi-angle approach, taking into account technical, business and regulatory perspectives. Therefore, industry leaders must define a clear set of key action items and necessary first steps to set the scene for Blockchain adoption. This section aims to provide a set of recommendations to boost Blockchain in the Mexican Energy Sector.

Experts from both the Energy Sector and Blockchain technology pointed out several important actions to reckon when designing an industry wide strategy. All inputs were analyzed and summarized in 6 steps, shown in graph 5.1. The following recommendations are not focused towards instantly deploying commercially available Blockchain solutions in the market, but rather for laying the foundations required for a Blockchain ecosystem in which real use cases with high impact can truly thrive.

Graph 5.1 – Recommendations for Blockchain Adoption



Energy Partnership, 2020

Education, Training and Skill Development

As repeatedly mentioned throughout the consultation, interview and workshop processes carried out with experts, the market requires education and training to develop the required skillsets and capabilities for an industry wide Blockchain adoption. In fact, 75% of consulted experts identified a lack of skills and understanding as the one of the five main barriers in adopting Blockchain within the Energy Sector. This result not only positions it as the top barrier over all, but also as the most critical one, being ranked as the main constraint by

30% of respondents. Having this in mind, education is considered as the first key step in the Blockchain journey for the Energy Sector.

Training will not be the same for all participants involved in these initiatives, the level of depth and technical knowledge will vary according to the assigned role within the Blockchain strategy. Similar to other technologies, understanding the underlying technology along with complex concepts is not required by all stakeholders for implementation. Most participants will require an executive level awareness of Blockchain that will allow them to identify value areas for applying the technology, whereas the development of the solution itself will require technical training and skills. Some examples of profiles that must receive an executive and conceptual formation include stakeholders and decision-makers, digitalization and innovation specialists, legal and business consultants, project managers, product owners, development representatives, research analysts, regulators and policymakers. High technical and development skills on the other hand will be required for roles such as Blockchain engineers, architects, developers, data scientists and cybersecurity professionals.

Business Case Development and Impact Assessment

Once participants have an understanding of the technology, along with necessary tools and skills for identifying opportunity areas for Blockchain, potential use cases must be evaluated. The objective will be to provide stakeholders with the necessary information to identify associated costs, revenues, social impacts, risks and benefits. Mapping out the future state with a Blockchain solution in place is the first step for developing an impact assessment and business case for the selected use case. The business case must include a return on investment (ROI) analysis, where organizations will qualify a specific use case from a cost-benefit perspective.

A revenue impact will show new or enhanced revenues streams derived from the proposed business model and the enablement of new digital channels. This analysis can also include impacts from cost savings, reduced capital consumption, access to new markets, loss reductions and increased efficiency. Afterwards a cost impact evaluates initial investments required for implementing the use case, including infrastructure setup, system integrations, technological developments, access to required human capital, regulatory compliance and business transformation. This analysis will provide business insights to stakeholders for investment decisions.

In parallel, an impact assessment will provide additional information beyond a purely business focus. This evaluation is based on a proposed future state in which the target operating model is reviewed, providing critical inputs of the expected impacts for a selected use case.

This assessment helps measure other factors that may be more relevant for regulators, policy makers, TSO's, and final users by providing information on what impacts it will have from a social, economic, regulatory, sustainability and political point of view. A common tool used in project evaluation is the Internal Rate of Return (IRR), a metric used to estimate profitability of investments by making the net present value of a certain project equal to cero. Additionally, decarbonization through incentives for green energy consumption and positive social impacts by increasing market competition and cost reductions for final users may also be taken into account within this assessment.

Clear Communication and Coordination Strategy

Even a Blockchain solution with high impact for the industry and strong feasibility for implementation can fail if it doesn't onboard the necessary participants for network effects to take place. In other words, if the solution doesn't manage to coordinate enough relevant players to join the network, expected benefits and overall impacts will not be achieved. It is for this reason that it becomes of extreme importance to design a communication strategy that clearly outlines the market needs it is trying to solve, along with its associated benefits, advantages, risks and challenges.

Communication with regulators, authorities and policy makers is essential in this process. Private organizations must be able to transmit industry needs to them and explain how Blockchain solutions could help tackle them.

This can be done by showcasing successful use cases at an international level as a benchmark for what could be implemented in the local market. This effort shall be complemented with research and development focused specifically to the Mexican Energy Sector and small-scale testing in a controlled environment to understand how the use case could be deployed considering important local factors. Regulators will first require a clear understanding of the technology and how it can help solve a shared industry need while generating social and economic impacts. Only then will they consider Blockchain-based business and operative models, along with making necessary adoptions to the regulatory frameworks to support them.

Minimum Viable Ecosystem and Governance Model

Having key stakeholders and industry leaders on board with a potential Blockchain solution is not enough, a minimum viable ecosystem must be established to test if the intended interactions among participants with varying interests and objectives is in fact feasible and sustainable. The objective of setting up this ecosystem is to form a simplified version of a future highly complex ecosystem where participants can actively learn and collaborate. One of the most important tasks of this ecosystem is the definition of a governance body for future industry-wide applications.

Consequently, setting up an industry Blockchain consortium with interested market players is an initial approach to establish the overall objectives of Blockchain adoption, while offering an environment for pilots and testing.

Moreover, a consortium initiative will offer a space for involved parties to organize themselves towards a shared goal by defining industry priorities, selecting leadership for this initiative and designing the Blockchain's governance body. Key aspects for the consortium to decide, in collaboration with regulators, is the network's decentralization degree by choosing from a public or private Blockchain and establishing accessibility rules in case of opting for a permissioned model.

Definition of Standard Frameworks and Guidelines

Moving to industry-wide Blockchain implementations will require standards and guidelines for all participants to follow. A starting point for achieving this is to identify international best practices of the specific process to develop local and/or regional frameworks, as well as to set up technological guidelines that facilitate software and hardware integration for participants. Once more, this step will require high involvement and inputs from regulators and relevant authorities in order to develop the required industry standards in favor of all participants. Additionally, stakeholders will need to fully understand and take into account the direction the Mexican energy policy is taking to align their objectives and focus on viable solutions.

Sandbox and Testing Environments

The final recommended step is to set up a closed and controlled environment where Blockchain use cases can be designed, developed and tested in order to fully understand the proposed business model along with associated benefits, impacts, risks and challenges that could arise when scaling it. Being able to pilot use cases before a full scale implementation will help players understand the technology through basic solutions that can solve specific problems. As Juan Roberto Lozano mentioned, it is recommendable to test initial applications in technical and internal processes before launching unproven solutions that may have direct impacts to the market.

A Sandbox environment is also extremely useful for regulators and policymakers to understand Blockchain business models. The best way for regulators to understand this technology is through the creation of regulatory sandboxes, where private organizations can test solutions under regulatory supervision in a controlled environment, providing valuable information for regulators to make necessary adoptions to existing frameworks in order to foster Blockchain adoption. This will also improve communication regarding market needs, innovative solutions and prominent industry trends. An alternative option to a regulatory sandbox is for private organizations to voluntarily set up testing environments where they can demonstrate use cases to report social impacts and industry-wide benefits to regulators for them to evaluate what applications they are interested in adopting.

The six steps reviewed must not necessarily be viewed as a linear process, but rather as general guidelines that industry leaders can use when designing their Blockchain strategy, as well as for other digital transformation initiatives being considered. These recommendations focus on short and medium term objectives, aiming to lay solid foundations for long term projects to be successful and be able maximize their potential.

5.3 Conclusions

Digitalization must be understood as a process, where the integration and implementation of digital technologies within the energy system have to go hand-in-hand with the Energy Transition. The adoption of renewable energy, DER infrastructure, batteries, smart devices and alternative energy sources in the Mexican market need to be complemented with new technologies that allow the industry to advance towards the decarbonization and decentralization of the system. The Energy Sector continues to face significant challenges and it is through technological advancements and innovate tools such as AI, IoT, data analytics, cloud computing and Blockchain that the industry will be able to overcome them.

Said challenges are also accompanied by three key trends in the industry: digitalization, decentralization and decarbonization. Efforts in these areas are essential for the ongoing evolution of the industry due to significant changes it is currently facing. Digitalization, for example, is crucial to achieve cost reductions, streamline processes, optimize revenue streams, enhance data management and improve coordination in an increasingly complex energy system. Decentralization on the other hand provides multiple benefits to the Energy Sector, including the enablement of DER infrastructure, increase market competition, lower prices for final users, enhanced grid flexibility and improved access to renewable and local energy sources. Finally, decarbonization is an industry priority that continues to pressure stakeholders towards achieving sustainability and climate change objectives. The Energy Transition requires strong efforts focused in these three fundamental pillars to succeed, and market participants must leverage the use of digital technologies such as Blockchain during this journey.

Apart from the challenges that the Energy Sector is dealing with at an international level, Mexico has additional obstacles to overcome, specific to its local context. One important barrier for adopting digital technologies is the prevalence of obsolete infrastructure throughout the entire energy value chain, representing an issue for organizations that want to test or deploy digital solutions

in the market. Another case is the lack of human capital with the required talent and skillsets for engaging in a digital transformation strategy; there is available talent in the Mexican market, however, efforts in the industry are not integrated and there is no clear strategy to organize market participants. The last challenge is related to market uncertainty in regulatory and political terms. This aspect requires clear frameworks and guidelines throughout the decision-making process of key players that are looking for opportunities to invest and develop technological solutions in the Mexican Energy Sector.

Despite these challenges it is critical to maintain market trends as a strategic priority at both an industry and organizational level. Blockchain is a strategic technology to consider within digital transformation initiatives across the Energy Sector given its potential impact across all 3 major trends. Its underlying characteristics such as transparency, traceability, immutability and distributed trust can offer industry leaders interesting functionalities worth evaluating when developing new business models or technological solutions to overcome specific challenges.

Blockchain is considered to be a disruptive technology due to its characteristics and potential benefits across multiple industries, but this is not the case for the Energy Sector. Rather than a disruptor it should be perceived as an enabler to accelerate disruption. Industry leaders and stakeholders must understand that the main factor which is truly disrupting the sector is the Energy Transition itself, along with the increasing amounts of data and complexity that is being introduced into the system. Taking this into account, Blockchain is an excellent tool to overcome significant barriers in coordination, traceability, transparency and decentralization.

Although Blockchain has seen significant advances in recent years it is still considered to be a developing technology that is going through a maturing process. It has gained importance across multiple fields, where the most advanced use cases are found in fields such as cryptocurrencies and payments, banking and finance, insurance, supply chain and digital identities. The Energy Sector is one of the many industries that has shown an increasing interest in recent years, exploring applications that seek to exploit its decentralized nature through tokenization models, smart contracts and the creation of distributed ecosystems.

It is also important to point out that this technology has experienced several events throughout its life-cycle that have generated doubt and skepticism among stakeholders. Clear examples include cryptocurrency crashes, ICO frauds, market volatility and an unclear regulatory response from authorities. An equally important aspect to consider is that Blockchain can offer a wide array of opportunities that go beyond the hype and focalized marketing attention which have caused over-expectations of this technology. In this sense, Blockchain has surpassed a disillusionment phase which has calmed market expectations. Therefore, it is no longer perceived as a universal remedy which can be applied into any situation that comes to mind, but rather as a helpful tool that can be used under certain circumstances to solve very specific problems.

In order to harness the full potential of Blockchain, industry leaders must have several aspects present before heading into testing and development phases. One key aspect is a paradigm shift in the way industry-wide collaboration is carried out. A Blockchain solution makes most sense when there are multiple parties involved and benefits are maximized when a distributed ecosystem is created. Although there are tangible individual benefits for organizations that adopt this technology, it is necessary to lay the foundations for an industry-wide Blockchain solution to thrive in the market.

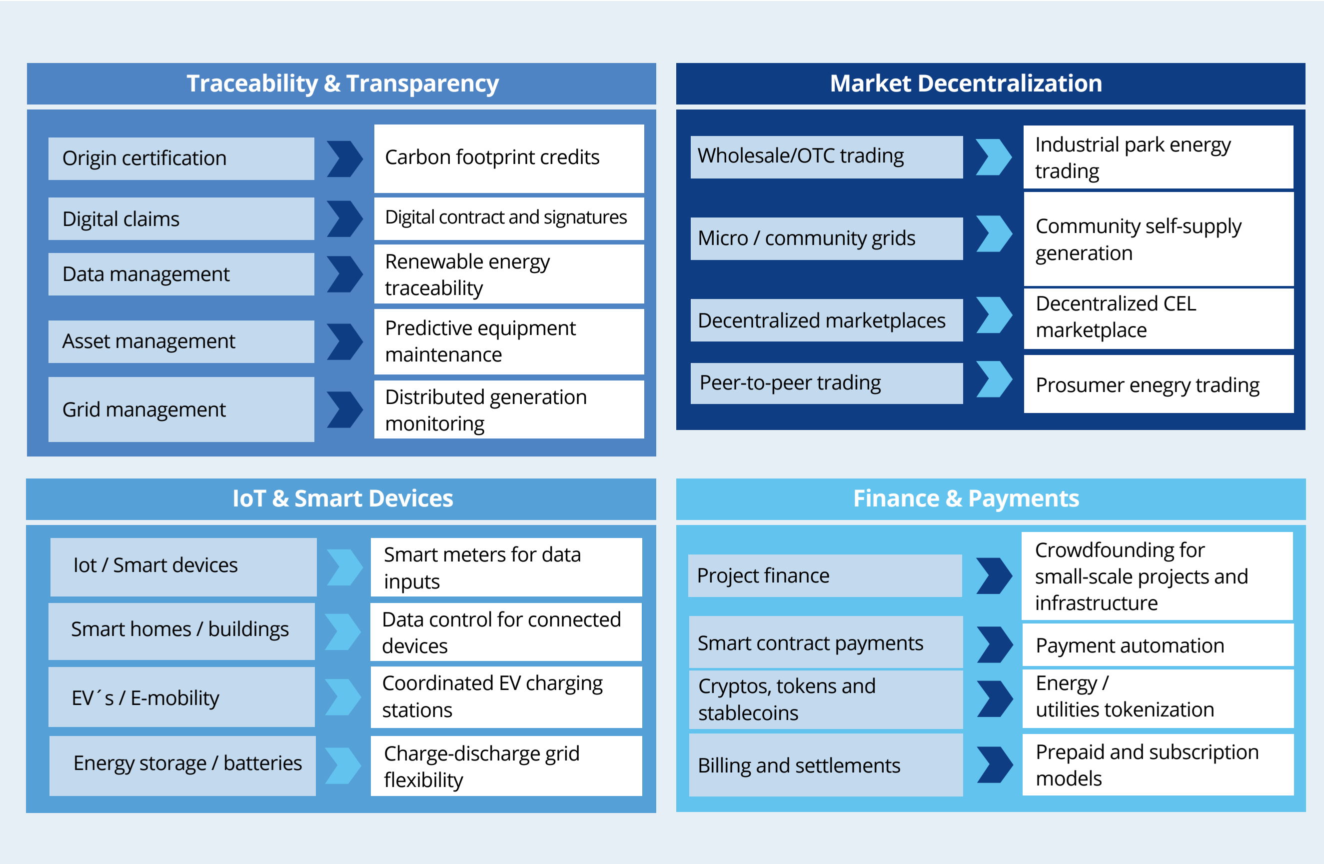
Some examples include: close collaboration with competitors (known as "coopetition"), well-coordinated efforts among stakeholders and co-investments from relevant actors. This can be achieved through the establishment of and industry Blockchain consortium, where each actor assumes a specific role, industry priorities are clearly established and leadership for Blockchain initiatives is defined. The objective is to facilitate coordination for developing a solution that provides benefits and positive impacts to all participants involved.

Furthermore, Blockchain should not be seen as a one-size-fits-all solution. There are several variants available in terms of privacy, security, decentralization, scalability and transaction speed. These characteristics are defined by the architecture model, network governance structure and consensus mechanism used, which will be defined by the solution's main objective and the overall purpose of the distributed ledger. This definition is one of the main challenges when designing a Blockchain-based application; experts refer to this as the Blockchain Trilema: finding the right balance in terms of security, scalability and decentralization; an increase in two out of the three elements will require a sacrifice in the remaining one. Therefore, industry leaders in the Energy Sector will have to evaluate and prioritize these characteristics, choosing two as the main drivers of the solution and leaving the third in second term.

There are also significant risks to have in mind when qualifying Blockchain use cases. Initially, an organization must focus on use cases that actually make sense, there is a wide market misunderstanding of this technology, which can result in substantial investments in a solution that is destined to fail. Another risk area is associated to cost-benefit assessments when building a business case, as it can be difficult to identify a quantifiable added value and ROI due to limited benchmark information on other projects and initiatives. Moreover, other risks to consider include: vulnerabilities in a consensus mechanism that can result in untruthful behaviors from network participants; regulatory uncertainty for certain business models; lack of specialized talent and internal capabilities for Blockchain implementation projects; data privacy and cybersecurity concerns; and lastly, high industry barriers due to the high strategic nature of the Energy Sector.

The Energy Sector has already begun to explore the use of Blockchain technology. There are several projects and initiatives at an international level that are already testing the technology through pilots and small-scale solution across different points of the value chain, aiming to find prominent use cases and to demonstrate successful applications. Blockchain-based business models identified for the Energy Sector can be categorized into the following 4 groups, along with their corresponding sub-categories:

Graph 5.2 – Categorization of Blockchain-based Business Models



Energy Partnership, 2020

There are certain business models that currently offer the most prominent and feasible use cases at an international level, mainly due to the maturity level of Blockchain technology and the market ecosystem to foster this type of solutions. Origin certification is possibly the most advanced application thanks to high market interest and low regulatory and infrastructure barriers. Wholesale trading seems to be the sub-category with highest impact looking at short-term opportunities, given that this type of business models are already considered in the Mexican regulatory framework, Blockchain would only serve as a digital platform to facilitate this process.

Finance & Payments business models are also highly developed within the Blockchain space, however there are increasing concerns from regulatory and risk perspectives, complicating the adoption of some use cases under this category. Consequently, solutions for billing and settlements show high feasibility since they are implemented throughout internal processes, allowing organizations to benefit from several Blockchain functionalities while mitigating market risks and avoiding regulatory uncertainty. Finally, business models associated to IoT and smart devices have seen lower market penetration given that IoT is also considered to be a maturing technology. However, this category is key for the development of future use cases, given that sub-categories found here will act as enablers for more complex solutions that will continue to emerge.

Taking this information into account, along with the experience, inputs and perspectives from experts in the Energy Sector and Blockchain technology, three key opportunity areas have been identified specifically for the Mexican Energy Sector. The first case is a decentralized CEL marketplace where relevant information regarding clean energy certificates is introduced, allowing market players to have clear accountability for clean energy generation while enabling counterparties to trade CELs through a digital platforms. Secondly is data and information accountability for contract enforcement, permitting users to leverage available data through smart contract functionalities in order to auto-execute certain pre-defined conditions, such as payments and settlements in PPA agreements. At last is a decentralized retail market for industrial parks, where a digital platform allows players within an industrial park to buy and sell energy through a digital wholesale energy marketplace in an efficient, transparent and secure way.

Private organizations must collaborate closely with the public sector when designing this type of use cases for them to gain traction. Regulators and authorities play a fundamental role to unlock the potential of Blockchain by establishing the regulatory framework which could either boost or discourage the adoption of this technology. It is critical to clearly communicate industry benefits and impacts that each use cases offers. This can be done through regulatory sandboxes or private testing environments where private organizations can test and evaluate use cases, which can then be showcased to regulators. This will help the public sector understand the benefits and risks that a solution brings forth, providing them with the necessary information to make adaptions to the existing regulatory frameworks, thus incentivizing and accelerating innovation in the sector.

In summary, Blockchain must be conceived as a tool that offers characteristics such as transparency, traceability, immutability and distributed trust to solve specific pain points. It should only be considered under certain scenarios where it truly makes sense to undergo a full-scale implementation. Each individual case must be evaluated separately to determine if Blockchain is a suitable solution. Furthermore, other technologies such as IoT, Data Analytics and AI must also form part of this assessment, as Blockchain will rarely offer high impacts and benefits alone. Blockchain is a strategic technology to consider when designing strategies to move towards digitalization, decentralization and decarbonization; however, each use case must be thoroughly evaluated and tested before deploying market grade solutions.

6. Bibliography

6.1 Primary Sources

GIZ experts in the energy sector, digitalization and blockchain technology.

KPMG experts in energy, digital transformation and blockchain technology.

Contributions from industry leader experts in the energy sector and blockchain technology through surveys, individual interviews and workshops.

6.2 Secondary Sources

Technical and conceptual

Allende, M. (2008). Cómo desarrollar confianza en entornos complejos para generar valor de impacto social. Washington, DC, US. Obtained from Inter-American Development Bank.

Aiim. (2020). Intelligent Information Management Glossary. Maryland, US. Obtained from Aiim web page: https://www.aiim.org/What-is-Robotic-Process-Automation#

Bakker Elkhuizen. (2020). What are virtual and augmented reality? Vugth, Netherlands. Obtained from Bakker Elkhuizen web page: https://www.bakkerelkhuizen.com/knowledge-center/what-are-virtual-and-augmented-reality/

Chamber of Deputies of the Mexican Federal Government (2018). Ley para regular las instituciones de tecnología financiera. Mexico City, Mexico. Obtained from Mexican Government web page: http://www.diputados.gob.mx/LeyesBiblio/pdf/LRITF_090318.pdf

GE Digital. (2019). Digital Twin, Digitize assets and processes to enable better industrial outcomes. California, US. Obtained from General Electric web page: https://www.ge.com/digital/applications/digital-twin

GlobalData Energy. (2019). Power utilities are placing their trust in robotics, reveals GlobalData. United Kingdom. Obtained from Power technology web page: https://www.power-technology.com/comment/power-utilities-are-placing-their-trust-in-robotics-reveals-globaldata/

Hertz-Shargel, B. & Livingston, D. (2019). Assessing Blockchains Future in Transactive Energy. Washington, D.C. US. Obtained from Atlantic Council, Global Energy Center.

International Energy Agency. (2017). Digitalization and Energy. Paris, France. Obtained from International Energy Agency web page: https://www.iea.org/reports/digitalisation-and-energy

KPMG US. (2016). Consensus: Immutable agreement for the Internet of value. New York, US. Obtained from KPMG

Microsoft Azure. (2019). What is cloud computing? Washington, US. Obtained from Microsoft web page: https://azure.microsoft.com/en-in/overview/what-is-cloud-computing/#uses

Mougayar. W. (2016). The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology. New Jersey, US.

Muykim, C. (2020). The Internet of Things (IoT): The Network of Networks. Phnom Penh, Cambodia. Obtained from Cambodia Development Center web page: http://cd-center.org/wp-content/uploads/2020/02/P127_20200210_V2IS1.pdf

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Obtained from web page: https://bitcoin.org/en/bitcoin-paper

Nhede, N. (2019). Blockchain in energy market to reach $3 billion by 2025. Cape Town, South Africa. Obtained from Smart Energy International web page: https://www.smart-energy.com/industry-sectors/energy-grid-management/Blockchain-in-energy-market-to-reach-3-billion-by-2025/#:~:text=Blockchain%20in%20the%20

Secretary of the Interior. (2019). Disposiciones de Carácter General aplicables a las Instituciones de Crédito e Instituciones de Tecnología Financiera en las Operaciones que Realicen con Activos Virtuales. Mexico City, Mexico. Obtained from Mexican government web page: http://www.dof.gob.mx/nota_detalle.php?codigo=5552303&fecha=08/03/2019

Swan, M. (2015). Blockchain: Blueprint for a New Economy. United States of America: O´Reilly Media Inc.

Tapscott, D. & Tapscott, A. (2016). Blockchain Revolution: How the Technology behind Bitcoin is Changing Money. US: Portfolio.

Tariq, S., Affzal, R & Zia, A. (2015). Transformer Failures, Causes & Impact. Bali, Indonesia. Obtained from International Conference Data Mining, web page: http://iieng.org/images/proceedings_pdf/8693E0215039.pdf

Vigna, P. & Casey, M. (2015). The Age of Cryptocurrency: How Bitcoin and the Blockchain are challenging the Global Economic Order. US: New York Times.

Mexican Energy Market

Alexandri, R., Rodríguez, F., Ángeles, A., García, E. & Ramírez, T. (2018). Prospectiva del sector eléctrico 2018 - 2032. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://base.energia.gob.mx/Prospectivas18-32/PSE_18_32_F.pdf

Alexandri, R., Villanueva, E., Muñozcano, L., Rodríguez, F., Rodríguez, J., Ramírez, A., Ángeles, A., García & E. Ramírez, T. (2018). Prospectiva de Energías Renovables. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://base.energia.gob.mx/Prospectivas18-32/PER_18_32_F.pdf

Bancomext (2019). México, Lugar 14 de Países con Más Inversión en Energía Renovable. Mexico City, Mexico. Obtained from Bancomext web page :
https://www.bancomext.com/notas-de-interes/25160

Beltrán, L., Villanueva, E., Muñozcano, L., Rodríguez, J., Ramírez, M., Portepetit, A., Ramírez, A., Rocha, D., Avila, D., Lourdes, M., Rangel, R., Ramones, F. (2018). Reporte de avance de energías limpias. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: https://www.gob.mx/cms/uploads/attachment/file/418391/RAEL_Primer_Semestre_2018.pdf

Chamber of Deputies. (2014). Ley de la industria Eléctrica. Mexico City, Mexico. Obtained from Mexican Government web page: http://www.diputados.gob.mx/LeyesBiblio/pdf/LIElec_110814.pdf

CENACE. (2017). Quiénes Somos. Mexico City, Mexico. Obtained from Mexican Government web page:
https://www.cenace.gob.mx/paginas/publicas/cenace/quienessomos.aspx

CRE. (2016). Preguntas Frecuentes sobre los Certificados de Energías Limpias. Mexico City, Mexico. Obtained from Mexican Government web page:
https://www.gob.mx/cre/articulos/preguntas-frecuentes-sobre-los-certificados-de-energias-limpias

CRE. (2018). La CRE aprueba reglas que detonarán la instalación de electrolineras y FIBRAs. Mexico City, Mexico. Obtained from Mexican Government web page:
https://www.gob.mx/cre/prensa/la-cre-aprueba-reglas-que-detonaran-la-instalacion-de-electrolineras-y-fibras?idiom=es

CRE. (2019). Evolución de Contratos de pequeña y Mediana Escala / generación Distribuida. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page:
https://www.gob.mx/cms/uploads/attachment/file/483322/Estadisticas_GD_2019-1.pdf

Hernandez, A. (2018). Autosuficiencia energética de México no se dará a corto plazo: AMLO. Mexico City, Mexico. Obtained from El Financiero web page:
https://elfinanciero.com.mx/nacional/cfe-generara-competencia-con-proveedores-de-energia-para-abaratar-tarifas-lopez-obrador

INEGI. (2019). Mexico City, Mexico. Obtained from INEGI web page:
https://www.inegi.org.mx/sistemas/bie/

Limón, A. (2019). Diagnóstico de costos de congestión en la Red Nacional de Transmisión. Mexico City, Mexico. Obtained from CIEP web page:
https://ciep.mx/diagnostico-de-costos-de-congestion-en-la-red-nacional-de-transmision/

Padilla, A., Chávez, I., García, D., Hernández, G. & Rosalgel, S. (2019). Energías Renovables: Construyendo un México Sustentable. Mexico City, Mexico. Obtained from BANCOMEXT web page:
https://www.bancomext.com/wp-content/uploads/2019/01/Libro-Bancomext_Energias-Renovables.pdf

Subsecretary of Electricity. (2014). CONTRATOS LEGADOS PARA EL SUMINISTRO BÁSICO. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page :
https://www.gob.mx/cms/uploads/attachment/file/258356/Nota_explicativa_contratos_legados.pdf

Secretary of Energy of Mexico. (2015). Explicación ampliada de la Reforma Energética. Mexico City, Mexico. Obtained from Mexican Government web page:
https://www.gob.mx/sener/documentos/explicacion-ampliada-de-la-reforma-energetica

Secretary of Energy of Mexico. (2016). Programa Nacional Para Aprovechamiento Sustentable de la Energía. Mexico City, Mexico. Obtained from Secretary of Energy of Mexico web page: México, México. Obtenido de Gobierno de México Sitio web:
https://www.gob.mx/cms/uploads/attachment/file/475503/PRODESEN_indice.pdf

Secretary of Energy of Mexico. (2019). Programa de Desarrollo del Sistema Eléctrico Nacional PRODESEN 2019-2033. Mexico City, Mexico. Obtained from Mexican Government web page:
https://www.gob.mx/cms/uploads/attachment/file/475503/PRODESEN_indice.pdf

Secretary of Environment and Natural Resources of Mexico. (2018). ¿Qué son las energías renovables? Mexico City, Mexico. Obtained from Mexican Government web page: https://www.gob.mx/semarnat/es/articulos/que-son-las-energias-renovables?idiom=es

Markets and statistics

Barontini, C. & Holden, H. (2019). Proceeding with caution – a survey on central bank digital currency. Basel, Switzerland. Obtained from Bank for International Settlements web page:
https://www.bis.org/publ/bppdf/bispap101.pdf

IRENA. (2019). Renewable Energy Statistics 2019, Abu Dhabi, UAE. Obtained from The International Renewable Energy Agency.

Kaggle. (2017). Kaggle ML & DS Survey A big picture view of the state of data science and machine learning. California, US Obtained from Kaggle web page:
https://www.kaggle.com/kaggle/kaggle-survey-2017

Ritchie, H. & Roser, M. (2019). CO_2 and Greenhouse Gas Emissions. Oxford, England. Obtained from Our World in Data web page:
https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Reference Cases

Boucher, P. (2017). How blockchain technology could change our lives. Brussels, Belgium. Obtained from European Parliament Research Service: Scientific Foresight Unit (STOA). web page:
https://www.europarl.europa.eu/RegData/etudes/IDAN/2017/581948/EPRS_IDA(2017)581948_EN.pdf

Emmi. (2018). The greatest source of systemic risk to global capital markets is climate change. Melbourne, Victoria. Obtained from Emmi web page: emmi.io

Energy Web. (2019). Blockchain: TEO (The Energy Origin) is the first application to migrate onto the Energy Web Chain. Zug,

Switzerland. Obtained from Energy Web Foundation web page: https://www.energyweb.org/2019/09/19/blockchain-teo-the-energy-origin-is-the-first-application-to-migrate-onto-the-energy-web-chain/

Energy Web. (2019). EW-DOS: The Energy Web Decentralized Operating System An Open-Source Technology Stack to Accelerate the Energy Transition. Berlin, Germany. Obtained from Energy Web Foundation web page: https://www.energyweb.org/wp-content/uploads/2019/12/EnergyWeb-EWDOS-VisionPurpose-vFinal-20200309.pdf

Folk, E. (2019). How IoT is Transforming the Energy Industry. Dakota, US. Obtained from Renewable Energy Magazine web page: https://www.renewableenergymagazine.com/emily-folk/how-iot-is-transforming-the-energy-industry-20190418

Ghosh, A., Rhodes, Y., Ternullo, S. & Caron, K. (2020). Harnessing technology convergence to manage climate change. New York, US. Obtained from KPMG US web page: https://advisory.kpmg.us/content/dam/advisory/en/pdfs/2020/kpmg-harnessing-tech-convergence-manage-climate-change.pdf

GuildOne. (2019). ConTracks: GuildOne's Smart Contract Engine. Calgary, Alberta. Obtained from Guildone web page: https://guild1.co/contracks-smart-contract-engine-on-blockchain/

Heredia, D. & Reyes, A. (2014). Robótica aplicada al sector eléctrico. Mexico City, Mexico. Obtained from the National Institute of Electricity and Clean Energies web page: https://www.ineel.mx/boletin042014/divulga.pdf

International Energy Agency. (2017). Digitalization & Energy. Paris, France. Obtained from International Energy Agency web page: https://webstore.iea.org/download/direct/269

International Energy Agency. (2019). Global EV Outlook 2019. Paris, France. Obtained from International Energy Agency web page: https://webstore.iea.org/download/direct/2807?fileName=Global_EV_Outlook_2019.pdf

IOTA. (2019). Opening Data For Smarter Communities. Berlin, Germany Obtained from IOTA web page: https://www.iota.org/solutions/smart-city

IRENA. (2019). Innovation landscape brief: Utility-scale batteries. Abu Dhabi, UAE. Obtained from International Renewable Energy Agency.

IRENA. (2019). IRENA Innovation Landscape 2019. Abu Dhabi, UAE. Obtained from IRENA web page: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Landscape_2019_report.pdf

IRENA. (2019). Finance & Investment. Abu Dhabi, UAE. Obtained from IRENA web page: https://www.irena.org/financeinvestment

KPMG International. (2016). Missing link: Navigating the disruption risks of Blockchain. Obtained from International https://home.kpmg/sg/en/home/insights/2016/11/missing-link-navigating-the-disruption-risks-of-blockchain.html

KPMG International. (2018). Blockchain and the future of finance: A potential new world for CFOs – and how to prepare. Obtained from KPMG International

Lumit. (2019). Cincel. Mexico City, Mexico. Obtained from Lumit Blockchain web page: https://www.cincel.digital/

Lumit. (2017). Soluciones Blockchain para México y LATAM. Mexico City, Mexico. Obtained from Lumit Blockchain web page: https://www.lumitblockchain.com/language/es/

Main, D. (2019). Developers community update: IOTA & +CityxChange Berlin, Germany Obtained from IOTA web page: https://blog.iota.org/iota-cityxchange-community-update-85f43894bcca

Peter, V., Paredes, J., Rosado, M., Soto, E. Hermosilla, D. (2019). Blockchain meets Energy. Mexico City, Mexico. Obtained from German-Mexican Energy Partnership (EP) and Florence School of Regulation (FSR) web page: https://fsr.eui.eu/wp-content/uploads/Blockchain_meets_Energy_-_ENG.pdf

Phineal. (2013). Tecnología inspirada en la naturaleza. Santiago, Chile. Obtained from Phineal web page: https://www.phineal.com/

Richard, P., Mamel, S. & Vogel, L. (2019). Blockchain in the integrated energy transition. Berlin, Germany Obtained from Deutsche Energie-Agentur GmbH web page: https://effizienzgebaeude.dena.de/fileadmin/dena/Publikationen/PDFs/2019/dena-Studie_Blockchain_Integrierte_Energiewende_EN2.pdf

R3. (2019). Customers Energy. New York, US Obtained from R3 web page: https://www.r3.com/customers/energy/

Siemens. (2019). e-ing3ni@ Platform. Madrid, Spain. Obtained from Siemens web page: https://new.siemens.com/global/en/company/topic-areas/energy-transition/e-ingenia.html

Statista. (2018). Size of the blockchain technology market worldwide from 2018 to 2025. Hamburg, Germany. Obtained from Statista web page: https://www.statista.com/statistics/647231/worldwide-blockchain-technology-market-size/

United Nations. (2015). Paris Agreement. Paris, France. Obtained from United Nations web page: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

Uruguay´s Presidency. (2019). Uruguay cuenta con 98 % de energía renovable y redujo emisiones de gases de efecto invernadero. Monte Video, Uruguay. Obtained from Uruguay+s presidency web page:
https://www.presidencia.gub.uy/comunicacion/comunicacionnoticias/ministra-eneida-de-leon-en-sesion-de-naciones-unidas-reduccion-gases-efecto-invernadero

WePower. (2017). The easiest way to buy green energy directly from producers and reach your energy sustainability goals. Vilnius, Lithuania. Obtained from WePower web page:
https://www.wepower.com/

Wynn, G. (2018). Power-Industry Transition, Here and Now Wind and Solar Won't Break the Grid: Nine Case Studies. Cleveland, US. Obtained from Institute for Energy Economics and Financial Analysis web page:
https://ieefa.org/wp-content/uploads/2018/02/Power-Industry-Transition-Here-and-Now_February-2018.pdf

Wynn, G. (2018). A Renewable Energy Revolution in Uruguay for All the World to See. Cleveland, US. Obtained from Institute for Energy Economics and Financial Analysis web page:
https://ieefa.org/ieefa-update-a-renewable-energy-revolution-in-uruguay-for-all-the-world-to-see/