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Prospection in Energy Digitalization in Chile

CENTRO DE ENERGÍA
FCFM UNIVERSIDAD DE CHILE

IMPRINT

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1 Table of Contents

Executive Summary

The digital revolution is happening in all sectors. Although some applications of digital technologies are more evident to users than other (i.e., smart phone apps), energy is one of the areas that has benefitted the most by this revolution. The energy sector has seen an expansion in possibilities, transitioning from an industry of traditional services to a highly complex multi-actor system. Today, we hear about renewable energies, smart grids, prosumers, and many other terms that could not have been imagined without those technological advancements. However, this sector has the big challenge of moving towards a consumer-centric (or end-user-centric) paradigm, taking advantage of the opportunities given by digitalization.

In this way, the energy sector presents an interesting opportunity to create value by combining digital technology, people and business strategy and reducing carbon emissions trough the way we produce and consume electricity, safeguarding the planet for future generations. We hope that digitalization will become a fundamental factor for the energy transition and an enabler of industrial trends related to decarbonization and decentralization.

A state-of-the-art review of the digital revolution was performed, as well as an analysis of gaps and opportunities for digitalization applications, with a focus on energy and the associated sectors. The review included scientific publications as well as policy from ten key countries that were selected for their merits in an international digitalization ranking: Germany, Finland, Japan, China, USA, UK, Sweden, France, South Korea and Singapore. From this review, a total of 30 key uses/applications were identified, along with eight classes that group related applications. Several enabling technologies were also identified, divided in six categories.

From the analysis, smart grid technologies and uses are prevalent. Enabling technologies on the Internet of Things category are those most often found in digitalization uses. Big Data, Machine Learning and Artificial Intelligence technologies are usually found in the customer domain uses, which are key when taking into consideration that an end-user-centric vision is usually associated with the digital transformation, according to the literature.

In addition, the analysis helped identifying digital uses and applications that support or incentivize the development of the measures included in the updated Nationally Determined Contributions (NDC) proposal and the carbon neutrality target by 2050. In general, most of the identified digital uses and applications are not included explicitly in the NDC: Eight applications and uses were found to contribute directly to mitigation actions proposed in the NDC, while four applications, although not associated with a specific measure, contribute indirectly to the carbon neutrality target.

The analysis of gaps and opportunities was performed both for the key countries as well as for Chile. This included the goals that the key countries have set for themselves, what gaps they are (or were) associated with, the barriers that digital uses and applications have had to face, and the main opportunities associated with digital uses and applications. The main barriers for the identified applications are summarized below:

- **Economic:** Most of the digitalization uses face economic barriers, such as the lack of economic incentives to implement an application or to deploy a technology. Also, the high investment cost of several technologies appears frequently as a barrier.
- **Regulatory:** Several applications require a modification or update of the current regulation. This is notorious on the Smart Grid, DER Management and Customer domain classes of applications, and in a lesser degree in the Mobility class of applications.
- **Infrastructure:** Barriers found on the technical level, related to the deployment of enabling technologies or the required infrastructure for an application to succeed were also found. Because of the variety of barriers included under Infrastructure, these were found across all classes.
- **Security:** Privacy, data sovereignty and information security were also barriers recognized across all classes of uses.
- **Human Capital:** Several applications, particularly those that involve and benefit customers or end users, were recognized as having barriers on the lack of training and the need of new skills, knowledge and digital education.

The opportunities for digital applications in Chile can be summarized as follows:

- **Smart grids:** These technologies present a great opportunity for both urban and rural zones, with solution that improve access to energy services and their quality.
- **DER management:** The growing penetration of renewable energies at the national level, empowered by the country's goals, brings opportunities for new uses associated with distributed resources. The modernization of the distribution systems regulation opens new possibilities for uses such as demand response and distributed storage
- **Customer domain:** Uses of this class can impact directly the customer's service experience and engagement with the energy sector as they can offer customer-tailored energy products with a wide range of incentives and features.
- **Process management:** The incorporation of these uses entails an improvement in the efficiency of the processes through the deployment of equipment and technology, as well as an increase in the satisfaction levels of employees and the creation of new job profiles.
- **Mobility:** Digitalization favors the reduction of emissions by making the transfer of goods and people more efficient, for example, reducing the number of simultaneous vehicles in the streets and the transit time of each vehicle, or fostering the adoption of electric vehicles in the extent to which it can generate added value to the owners (vehicle-to-grid services, smart charging networks, etc.).
- **Data management:** Data management technologies present an important opportunity to take advantage of the abundant renewable energy resources of Chile, as well as to better understand demand (elasticity, patterns, etc.) for electricity, transport and heating.
- **Smart city:** Digital applications in this class bring social benefits associated with an increase in social well-being, improved road safety, reduced travel times, better services, reduced visual and olfactory pollution, increased quality of life, among others, contributing to the reduction of GHG emissions, through the efficient management of energy and water, the reduction of fuel consumption and the improvement of production processes.
- **Other uses:** Specific opportunities were recognized for each use under this class, where contribution to emission reduction was transversally recognized. Teleworking, in particular, has gained more visibility during the 2020 pandemic.

Considering the international experiences, the following recommendations for public policies are considered in order to reduce barriers and promote the implementation of uses and digital applications:

- Promote articulation between the different institutions related to the digitization of the different sectors at the national level, considering a national policy approach.
- Promote and disseminate the existence of identified digital applications to the public and private sectors.
- Include the impact of the digitization of the energy sector in long-term energy policy and in climate change mitigation policies.
- Increase the public investments in digital infrastructure, build a large-sale ICT infrastructure that supports public utilities and other services such as road infrastructure.
- The adoption of a common data architecture, tools, and standards to reduce bugs and raise the quality, reliability, and security of devices and services, and that facilitates economies of scale and data sharing across different institutions.
- Reduce the digital gap among the different territories of the country.
- Increase investment in human resources and education related to digital application and enabling technologies.
- The implementation and reinforcement of Government's Personal Data Protection Laws and Policies for public and private sectors.
- Develop pilot programs to promote the use of different digital applications, involving the public sector, private sector, and academia.
- Encourage investment by private parties in projects associated with the digitization of the energy sector (greater offer of shared mobility, aggregators for VPPs, smart lighting services, etc.)

The full list of applications and enabling technologies are presented below, along with a summary sheet for each digital application class.

Digitalization uses and applications:

Class	Uses & applications
Smart grid	Smart substation
	Feeder automation
	Microgrids
DER management	Demand Side Management (DSM) / Demand Response (DR)
	Energy storage
	Virtual Power Plant (VPP)
	Distributed energy (electricity/DG & gas)
Customer domain	Prosumer & P2P trades
	Retailing, billing & customer orientation
Process management	Process optimization & automation (gas, oil & coal)
	Emission monitoring
Mobility	Transportation for personal use
	Public transport
	Transport cargo
	Shared mobility

Class	Uses & applications
Data management	Predictive maintenance
	Forecasting and predictive analytics
Smart city	Smart lighting
	Smart traffic
	Smart home & building
	Smart industry
	Smart farm
	Smart parking
	Smart waste management
	Smart fleet management
Other	Market management & operation
	Ancillary services
	Energy management
	Operation (monitoring/control/reporting)
	Teleworking

Enabling technologies:

Category	Enabling Technology
Smart home & Smart building	Load monitor
	In home display
	Smart thermostat
	Smart light
	Smart plug/switch
	Smart appliance
	Hub
Smart grid	Smart meters
	AMR/AMI
	V2G
	EV/PHEV
	IED (relays, SCADA, RTU, etc.)
	PMU
	WAMS

Category	Enabling Technology
IoT & IoE	Smart Sensors
	Sensor and actuator networks
	LAN/HAN/NAN/WAN
	Cloud
	5G
Big data, machine learning & AI Ledger	Machine learning
	Data mining
	Nature inspire intelligence
	Artificial Neural Networks (ANN)
	Multi-agent systems
	Clustering
	Natural language processing (NLP)
	Digital twin
	Autonomous Vehicle
	Blockchain
Physical action	Actuators
	3D printers

Smart Grid

Smart grid is a cyber-physical system which includes communication system with the power flow structure, to gain intelligence and automated control. The communication support schemes and real-time measurement techniques of smart grid enhance resiliency and forecasting as well as offer protection against internal and external threats.

Smart grid application potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Smart substation		X		X			Electricity
Feeder automation				X			Electricity
Microgrids	X	X	X	X		X	Electricity

Smart grid enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire ...	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Smart substation								x	x			x	x	x			x														
Feeder automation									x			x	x	x			x														
Microgrids								x	x	x	x	x	x		x	x	x	x													

Goals, gaps, barriers and opportunities for Smart Grid applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Smart substation	Modernization of the grid, monitoring and control to support flexible, secure grid.	Communication requirements in terms of transmission speed and security of information; Economic incentives.	Reduction in maintenance and operation costs; Increased safety; Reduced response time.
Feeder automation	Modernization of the grid, improved performance, integration of data analytics.	Investment (current digitalization level is low); Customer´s resistance to share information; Economic incentives, recognition of value-added services.	Faster response for reduced failure time; Synergy with DER.
Microgrids	Development of commercial microgrids, coexistence with centralized systems (current developments mostly at remote locations or labs).	Technical barriers (bidirectional power flow, stability, protection, coordination with centralized grids, safety); Lack of flexible regulation that permits bidirectional power flow, local energy trade; Lack of incentives to flexible resources.	Reliable and resilient grids; Incorporation of other digital applications (DER, customer domain); Synergy with DER; Association with SDG 7; Solution for rural areas.

Current goals for Chile:

- *Energía 2050*: 100% smart metering by 2050, intelligent communication and control to enable high renewables penetration, limits for outage durations (<1 hour per year by 2050).

Current initiatives in Chile:

- *Casa Solar* program (potential synergy with microgrids as complementary to the program).
- *Ruta de la luz* initiative (potential synergy with microgrids as rural electrification option).
- Energy policy update process by Ministry of Energy.
- *Anexo Técnico de Exigencias Mínimas de Diseño de Instalaciones de Transmisión* (specifications on smart substation topics).
- Coordinador Eléctrico Nacional is currently working on R&D (Fondef) project to incorporate PMU data in monitoring.

Public policy recommendations:

- Define sovereignty of the data explicitly in the regulation.
- Modernize technical normative: adopt common data architecture, tools and standards.

- Encourage investment by private parties in projects associated with digitization: recognize value-added services.

DER Management

DER Management alludes to the way in which the energy resources distributed in the electrical network are managed, seeking that said management efficiently take advantage of the availability of resources according to the conditions in which the system is found.

DER Management application potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
DSM/DR	X	X	X	X		X	Electricity
Energy storage	X	X	X	X		X	Electricity
VPP		X	X	X			Electricity
Distributed energy		X	X	X		X	Electricity

DER Management enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA …	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire …	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
DSM/DR			x		x	x		x	x					x			x	x													
Energy storage											x					x	x			x											
VPP																x	x	x		x											
Distributed energy																		x													x

Goals, gaps, barriers and opportunities for DER Management applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
DSM/DR	DR programs: tariffs and price schemes, flexible power goals (e.g. 200 MW in UK).	Lack of regulation that enables and incentivizes participation; Enabling technologies (e.g., smart meters); Maturity of smart appliances; Connectivity and access to information; Data security.	DSM/DR as a source of flexibility (e.g. controllability of the demand); Enabling technologies (Big data, AI) to improve operation; new customer services (e.g. smart pricing).
Energy storage	Overcome limits (e.g. 50 MW in UK) and reach specific targets (e.g. 200 MW by 2025 in Singapore), but usually associated with the goal of maximizing renewables penetration.	High investment cost in some technologies (e.g batteries); Regulation and participation on the market not fully defined; Potential conflict with displaced generators with long-term contracts (short term).	Storage as a source of flexibility (e.g. providing ramp capacity); Increased reliability and resilience.
VPP	*No specific targets were found*	Lack of regulation for VPP participation; Enabling technologies; Connectivity and computational cost.	Synergy with other digitalization uses (Microgrids, DG, DSM, storage, etc.), particularly as aggregators.
Distributed energy	Adoption goals either in terms of penetration (e.g. 15% in South Korea) or installed capacity (e.g. 15 GW dist. gas & 60 GW solar in China)	Regulatory barriers; Need to upgrade the electrical system in view of a bidirectional flow.	Lower cost associated with technological advances; potential contribution to emission reduction.

Current goals for Chile:

- *Energía 2050*: 70% renewable penetration by 2050, storage and demand as flexibility resource.
- *Ruta Energética 2018-2022*: 4-fold increase in renewable DG.
- New distribution systems law: new agents (Demand aggregator, Energy retailer, Information Manager).

Current initiatives in Chile:

- Updates to the Net billing law: Up to 300 kW of DG.

Public policy recommendations:

- Establish economic incentives for the participation of flexible resources in energy markets (energy, capacity, and ancillary services) that effectively reflect the value of their flexibility.

Customer domain

This class contains the uses whose focus is on the end user and how this participates in the system, considering aspects such as billing or the existence of the prosumer as a relevant agent for the energy system.

Customer domain application potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Prosumer & P2P trades		X	X	X			Electricity and fossil fuels
Retailing, billing & customer orientation	X			X	X	X	Electricity and fossil fuels

Customer domain enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire ...	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Prosumer & P2P trades								x									x												x		
Retailing, billing & customer orientation																				x	x	x			x	x					

Goals, gaps, barriers and opportunities for Customer domain applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Prosumer & P2P trades	Participation of a large number of consumers, especially small ones; There is a confidence or trust gap.	Data security must be ensured, ownership defined, and access to information guaranteed.	Creation of new services and markets; Highly compatible with the application of other uses (e.g. DG, DSM).
Retailing, billing & customer orientation	Open the retail energy market (e.g. gas, electricity) to full competition where users are free to choose suppliers.	Regulatory framework (must be tailored to the reality of each country); security and sovereignty of the information; lack of competition.	Improvement of user experience and engagement in this and other uses (e.g. EV, DSM).

Current goals for Chile:

- *Energía 2050*: prosumers recognized in policy, but no goals are set.
- New distribution systems law: electric portability (Energy retailer agent).

Current initiatives in Chile:

- phiNet (Phineal) is promoting energy traceability through blockchain technology (GTIME), current pilot at Transelec.

Public policy recommendations:

- Promote the entry of prosumers to the electricity market, incorporating economic incentives (taxes, tariffs) or the promotion of others that complement (e.g. energy storage).
- Promote the implementation of smart meters to facilitate the introduction of this type of schemes and to improve the quality of customer service.
- Promote competition and efficiency in energy trading.

Process Management

This class is associated with uses whose objective is to improve processes associated with energy generation and / or consumption and also for internal processes.

Process Management application potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Process optimization & automation (gas, oil & coal)	X	X	X	X			Electricity and fossil fuels
Emission monitoring		X		X			Fossil fuels

Process Management enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Process optimization & automation															x		x	x		x	x		x	x			x	x		x	x
Emission monitoring															x		x	x		x			x		x						

Goals, gaps, barriers and opportunities for Process Management applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Process optimization & automation (gas, oil & coal)	Increase satisfaction levels of employees; cut electricity usage; save fuel (e.g. airlines, vehicle fleets).	High investment cost; IT readiness; need for new skills; resistance from employees (potential job elimination), lack of trust, dependence on non-humans.	Improvement in process efficiency, economic benefits; creation of new jobs; Closely related to Smart Industry.
Emission monitoring	Zero emissions goals (e.g. COP 25 CO_2 goals); people's behavior and business ethics gap.	High cost of modernizing monitoring systems; lack of economic incentives.	Climate change mitigation actions.

Current goals for Chile:

- Carbon neutrality by 2050 (updated NDC).
- *Plan de Descarbonización de la Matriz Eléctrica* (decommissioning of coal power plants without carbon storage or sequestration).

Current initiatives in Chile:

- *Estrategia de Inteligencia Artificial para Chile*, from the Senate's Commission on Future Challenges, Science, Technology & Innovation.

Public policy recommendations:

- Promote digitalization (in particular, optimization and automation) on Small and Medium companies through economic instruments.

Mobility

This class includes those mobility applications that have incorporated digital technologies in some of their processes. Incorporation of mobility is important as transportation and electromobility are closely associated with energy.

Mobility applications potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Transportation for personal use	X		X				Fossil fuels and electricity
Public transport	X						Fossil fuels and electricity
Transport cargo	X						Fossil fuels and electricity
Shared mobility	X						Fossil fuels and electricity

Mobility applications enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire ...	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Transportation for personal use										x	x																	x			
Public transport										x	x																	x			
Transport cargo											x																	x			
Shared mobility										x	x									x						x	x	X			

Goals, gaps, barriers and opportunities for Mobility applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Transportation for personal use	Several infrastructure goals (e.g. charging stations) associated with the expected adoption of EVs.	Low market penetration of connectivity devices for vehicles; Lack of consensus on the technology to be massively adopted by vehicle manufacturers: Competition between IEEE 802.11 and 4G / 5G; Lack of regulation; High investment cost for EV; Prohibition for car conversion to electric	Overall customer satisfaction; Contribution to the mitigation of GHG emissions against climate change.
Public transport	Link with artificial intelligence strategies and their application in public transport (e.g. development of autonomous driving technology in South Korea).	High investment in infrastructure; Lack of incentives to prefer public transport over private.	Contribution to the mitigation of GHG emissions against climate change.
Transport cargo	Associated to zero emission policies (e.g. Sweden, UK)	Lack of ICT skills in freight companies.	Reduced operating cost through optimized logistics and automation.
Shared mobility	Require certain connectivity of vehicles and users. Interconnection between cities and introduction of large fleets of shared cars (Berlin is the city with the most car sharing).	Cybersecurity (exposed user location). The ownership of the information and access to the information must be defined.	Contributes to the mitigation of GHG emissions against climate change. Allows less crowding of public transport, desirable in situations of crisis (COVID-19).

Current goals for Chile:
- National Electromobility Strategy: 40% of private vehicles and 100% of public transportation by 2050.

Public policy recommendations:
- Flexible regulatory framework, which allows the implementation of shared mobility and the implementation of associated enabling technologies (autonomous vehicle, V2G, EV, among others).
- Legal definitions that establish rights, duties and responsibilities between the parties (users and providers of mobility services).

Data Management

This class groups uses oriented to data analysis using Smart Meters and / or AMIs. These uses allow to have a more reliable network for the information and forecasts that they deliver.

Data Management application potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Predictive maintenance	X	X	X	X		X	Electricity and fossil fuels
Forecasting and predictive analytics	X	X	X	X	X	X	Electricity and fossil fuels

Data Management enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire ...	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Predictive maintenance								x	x			x		x						x							x				
Forecasting and predictions																				x	x		x		x						

Goals, gaps, barriers and opportunities for Data Management applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Predictive maintenance	Need for greater penetration of technologies for maintenance and acquisition in real time, which entails an investment.	The existence of infrastructure that allows the acquisition of data is essential. High investment in complex systems. It requires significant use of computational resources.	Significant cost reduction. Increased safety of equipment operation by optimally managing maintenance.
Forecasting and predictive analytics	Massive implementation of this use; adoption of data acquisition technologies.	It needs incentives from relevant agents to adopt this use (eg utilities). The use of technologies with high costs means that this use has a relevant investment.	The high potential of renewable energies in Chile promotes the implementation of this use, considering that it allows for better adapted and planned responses. Complements the implementation of other uses.

Current goals for Chile:

- No public policies specifically related to this class.

Public policy recommendations:

- Promote policies to increase the public investments in digital infrastructure, build a large-sale ICT infrastructure.
- Promote articulation between the different institutions related to the digitization of the different sectors at the national level.
- Reduce the digital gap among the different territories of the country.
- Develop pilot programs to promote the use of different digital applications, involving the public, private sector, and academia sector, which may reduce the barriers of entry of different technologies.

Smart City

Smart City is a vision of future urban area where smart ICT technologies will connect every major sector of the city through rich features such as the smart economy, smart mobility, smart environment, smart people, smart living, and smart governance.

Smart City application potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Smart lighting		X	X			X	Electricity
Smart traffic	X	X				X	Electricity and fossil fuels
Smart home & building		X	X				Electricity and fossil fuels
Smart industry		X			X	X	Electricity and fossil fuels
Smart farm		X					Electricity and fossil fuels
Smart parking	X					X	Fossil fuels and electricity
Smart waste management		X	X			X	-
Smart fleet management	X	X				X	Fossil fuels and electricity

Smart City enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire ...	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Smart lighting		x		x											x	x	x		x											x	
Smart traffic									x																						
Smart home & building	x	x	x	x	x	x	x	x							x		x	x	x	x											
Smart industry						x									x			x		x	x				x			x			x
Smart farm			x	x	x			x							x		x	x	x	x	x				x					x	
Smart parking								x							x		x	x	x	x											
Smart waste management		x													x		x	x	x	x										x	
Smart fleet management										x	x				x		x	x	x	x								x			

Goals, gaps, barriers and opportunities for Smart City applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Smart lighting	Requires a remote monitoring and control system, capable of providing a quick and adapted response.	It requires a robust cybersecurity system against possible attacks. Its implementation must be supported by the state and socially, the public must be kept aware of its benefits.	Improves road safety in the city. Contributes to the efficient use of energy.
Smart traffic	Adoption of enabling technologies (VANETs, 5G).	Large investment due to the need for telecommunications infrastructure and fleet renewal or adaptation. Requires the analysis of large amounts of data and the integration of different platforms.	Contribution to emissions reduction.
Smart home & building	Develop broad standards in the smart home and building industries.	Sovereignty of information; lack of interoperability; cost of enabling technology.	Increased adoption of smart devices at home.
Smart industry	The transition process requires significant investments in equipment and staff training. SMEs cannot implement this use independently and therefore need government support (for example, the "Industry of the Future" initiative in France supported the modernization of more than 7,400 SMEs between 2016 and 2017).	It carries a high cost of implementation. There may be some resistance from employees.	Improves the efficiency of production processes. Digitization of the information handled by the industry allows obtaining simplified administrative processes.
Smart farm	Adoption of AI and automation in the agricultural industry.	Internet access must be guaranteed in mostly rural areas. Data sovereignty must be established. It is important to consider interoperability between producers.	Contributes against the climate crisis thanks to the efficient use of water. Boost agricultural productivity through new technologies (5G, IoT and Big Data).
Smart parking	Use of real-time information on parking facilities and interaction through mobile device apps.	Requires a real-time information system. Data security must be guaranteed. High investment in equipment and training.	Overall user satisfaction; smarter parking pricing.
Smart waste management	Goals such as zero waste and circular economy (e.g. Denmark); related to Emissions monitoring application.	Citizens must be trained so that the effects are consistent with change in behavior. It must be accompanied by incentives for companies to adopt this use. Investment in infrastructure (mainly sensors and telecommunications systems) and computational cost.	Contribution to emissions reduction. Use of emerging technologies. Increase in people's well-being.
Smart fleet management	Integration of information from different operators, sensors and services based on geolocation is needed. It requires the development of new technologies and specialized software. It needs non-existent infrastructure (VANET and 5G stations).	The ownership of the information and access to it must be established. It requires very fast communication systems and complex prediction algorithms.	It is associated with a reduction in GHG emissions, as well as a reduction in O&M costs. Reduces vehicular traffic congestion and optimizes travel times. Friendly with the incorporation of technologies (e.g. EVs and V2G). .

Current initiatives in Chile:

- Digital Agenda 2020: Strategic map of the Smart City Plan, allowed to recognize opportunities and gaps, in addition to the implementation of pilot projects.
- Santiago Smart City: public-private initiative promoted by CORFO and *Fundación País Digital*.

Public policy recommendations:

- Support companies for the development of innovation in software related to the efficient management of the city. Application of pilot projects that show the benefits for society.
- Accompany the implementation of any program or initiative by a campaign that aids in justifying the adoption of these uses.
- Consider citizen education plans for the use of applications that are directly related to daily work.
- Develop comprehensive strategic plans that include the implementation of various uses related to Smart City, in order to take advantage of synergistic opportunities and common solutions to detected gaps or barriers.

Other uses

Other applications potential by sector:

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Market management & operation				X	X		
Ancillary services	X	X	X	X			Electricity
Energy management	X	X	X	X			Fossil fuels and electricity
Operation (monitoring/control/reporting)				X			Electricity
Teleworking	X	X	X	X		X	Fossil fuels and electricity

Other applications enabling technologies:

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA ...	PMU	WAMS	Smart Sensors	Sensor and actuator	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire ...	ANN	Multi-agent systems	Clustering	NLP	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Market M&O																			x	x									x		
Ancillary services	x											x	x	x	x	x	x	x	x											x	
Energy mgmt..	x	x						x	x						x		x	x	x	x										x	
Operation								x	x			x	x	x	x	x	x			x			x						x	x	
Teleworking		x															x	x	x								x				x

Goals, gaps, barriers and opportunities for other applications:

Uses & applications	Goals & gaps	Barriers	Opportunities
Market management & operation	Move to decentralized, digitized systems, with new forms of transactions and empowered consumers.	Regulatory obstacles to new agents and ancillary services; Lack of incentives to share electricity data; data security.	New agents and markets that need management.
Ancillary services	Modernization of the grid (associated with Smart Grid class).	Need of a higher computational capacity for the implementation of new technologies (such as forecasting) in the ancillary services market.	Penetration of renewable energies, storage and EVs.
Energy management	Introduction and widespread use of Home Energy Management (associated with Smart Home and Building application).	Investment costs, low returns on capital; Lack or ignorance of economic incentives; Lack of regulation and governmental support; Low level of development of the ESCO model; Lack of in-house technical expertise; Difficulty measuring and verifying energy and cost savings.	Electrification of heat and smart applications (e.g. smart lighting); Development of Smart Home technologies.
Operation (monitoring/ control/reporting)	Reach a digital-enabled operation of energy systems; real-time operations.	Conflicts with privacy due to the use of user information; Distrust towards smart meters.	Reduction of cost and downtime.
Teleworking	Quick adoption (pushed by COVID-19); Improvement in infrastructure for cybersecurity; Telework policies at the corporate level.	Ambiguity between personal space and workspace; Need for connectivity improvements at residential level; Lack of employee training; Costs to enable good performance.	Reduction of expenses and transport times for workers. Encourage flexible hours. It is associated with the reduction of GHG emissions resulting from the non-use of transportation.

Current initiatives in Chile:

- Law 21.229 (Teleworking law) published on April 2020.
- Auction mechanisms in ancillary services.

Public policy recommendations:

- Increase the public investments in digital infrastructure, build a large-sale ICT infrastructure, including massification of 5G and AI technology.
- Promote the adoption of a common data architecture, tools, and standards to reduce bugs and raise the quality, reliability, and security of devices and services, and that facilitates economies of scale and data sharing across different institutions.

List of Acronyms

ADR	Automated demand response
ADAS	Advanced Driving Assistance System
AI	Artificial Intelligence
AMI	Advanced metering infrastructure
AMR	Automatic meter reading
ANN	Artificial neural network
AR	Augmented reality
BEMS	Building energy management system
BPL	Broadband over power line
CB	Circuit breaker
CER	Renewable energy certificate
CHP	Combined heat and power
CT	Current transformer
DER	Distributed energy resource
DG	Distributed generation
DR	Demand response
DSM	Demand side management
DSO	Distribution system operator
DSR	Demand side response
EaaS	Energy-as-a-service
EMC	Electromagnetic compatibility
EMS	Energy management systems
ESCO	Energy service company
EV	Electric vehicle
FA	Feeder automation
FFR	Firm frequency response
GHG	Greenhouse gases
GPS	Global positioning system
HAN	Home area network
HVAC	Heating, ventilation, and air conditioning
I-REC	International renewable energy certficates
ICT	Information and communication technology
IED	Intelligent electronic device
IHD	In home display
IoE	Internet of energy
IoT	Internet of things
IPS	Internet protocol suite
ISO	Independent system operator
IT	Information technology
LaaS	Lighting-as-a-service
LAN	Local area network
LCOE	Levelized cost of energy
MaaS	Mobility-as-a-service
NAN	Near-me area network
NCRE	Non-conventional renewable energy
NDC	Nationally determined contributions
NLP	Natural language processing
NPS	Net promoter score
O&M	Operations and maintenance
P2P	Peer to peer
PHEV	Plug-in hybrid electric vehicle
PMU	Phasor measurement unit

PPA	Power purchase agreement
PV	Photovoltaic
R&D	Research and development
REC	Renewable energy certificate
RPA	Robotics process automation
RTO	Regional transmission organization
RTU	Remote terminal units
SCADA	Supervisory control and data acquisition
SEMs	Small and medium-sized enterprises
SGIRM	Smart grid interoperability reference model
SLS	Smart lightning system
V2G	Vehicle-to-grid
VANET	Vehicular Ad Hoc networks
VPP	Virtual power plant
VR	Virtual reality
VT	Voltage transformer
WAMS	Wide area monitoring system
WAN	Wide area network
WLAN	Wireless local area network

Methodological note

Main goal

The main goal of the project is:

> *Review the international state-of-the-art of digitization in the energy sector describing potential applications associated with this concept in different sectors and establish the current situation of Chile in this matter. Determine the main barriers that must be resolved to advance in the development of the main applications associated with this topic in Chile.*

Specific goals

The specific goals are:

a) Raise the needs of digitization in the world and analyze why it is necessary to digitize processes in the energy sector from here to the future. Analyze how possible digitization applications can contribute to the GHG mitigation and especially with the NDC and with the Carbon Neutrality Strategy 2050 of Chile.
b) Determine which are the main digitalization applications in the energy sector in the world and in Chile.
c) Generate a database of minimum information that will allow to establish and prioritize public policy guidelines in order to enhance and advance the digitization in Chile with the perspective of Big Data analysis.
d) Create a map of present and future actors in the digitalization process in order to understand which actors are and/or could be the forerunners of digitalization.
e) Compile international accounts of public policies that seek to promote digitization in the energy sector.
f) Understand the challenge of digitization in its local dimension in order to enhance its national development, especially with reference to international examples and identifying opportunities and barriers.
g) Determine necessary legal modifications in order to implement and advance digitization in the energy sector.

Methodology

The methodology is divided into two separate sections, each corresponding to the Chapters 1 and 2 of this document.

State of the art

The state-of-the-art review has three main stages:

- **Review of the international state-of-the-art:** This part defines and explains what digitalization means and its application in the energy sector. The review includes international policy and practices, as well as a compendium on scientific research initiatives.
- **Digitalization uses, key countries, and actors:** This part identifies those countries that are more developed in the area of digitalization and highlights the mechanisms that have led to the successful implementation of digitalization initiatives (private efforts, public-private partnerships, public institutions, among others).
- **Usage map, impact on emissions, and business models:** This part develops a map of potential uses or applications of digitization, together with analyzing their impact on emission reduction, carbon-neutrality or other measures. It also contains a review of successful business models at the international level.

In addition, this report includes a comprehensive description of local actors in digitalization, along with information on the associated uses. Finally, the impact of digitalization uses in the NDC are presented.

Analysis of gaps and opportunities

The analysis of gaps and opportunities has three main parts:

- **Identification of current practices and gaps:** Fed by the review of the state of the art of Chapter 1, this part recognizes the current practices, policies and gaps on each of the uses previously identified. For this, the vision of the digitalization of the energy sector in the medium and long term is contrasted with the current situation of the experiences under consideration. Gaps are analyzed from both technical (technological and economic) and regulatory (political, social and environmental) perspectives.
- **Risks, impacts, opportunities and goals:** The risks and impacts associated with the use of information technologies, such as, vulnerability of people's privacy, cyber-attacks, increased dependence on electricity and telecommunications networks, increased dependence on the electricity grid, security of financial transactions, etc., are analyzed. The risks associated with the rebound effect on consumer behavior as a result of digitalization are also analyzed. Then, the main opportunities are identified, with examples such as cost reduction of energy services, improvement of wellbeing, acceleration of administrative tasks, innovation fostering, improvement of services security, among others.
- **Policies that promote digitalization:** A critical review of successful policies that promote digitalization in the energy sector and other related sectors is carried out. Special attention is paid to those involving citizenship participation, i.e. schemes that incorporate the participation of the end users in the applications.

In parallel with the international review, a recognition of local gaps and opportunities is also carried out. The opportunities identified for the different sectors were recognized, and their replicability at the national level is evaluated, considering those sectors that are strategic for the country's development model. For each use or application, the analysis identifies whether it is possible to replicate the opportunities in terms of: reducing the cost of electricity services, lowering the price of energy, improving the quality and security of supply, increasing people's wellbeing, eliminating administrative obstacles, creating new business models, promoting innovation, increasing the security of supply, and reducing the time spent without energy supply.

Report structure

Chapter 1 presents the state-of-the-art review. Section 2 presents the digitalization developments worldwide, including a comprehensive map of uses for digitalization-based technologies. Section 3 reviews successful business models associated with recognized digitalization uses. Finally, Section 4 presents the state of local developments, including a map of local actors and potential contributions of digitalization applications to the Chile's updated NDC.

Chapter 2 presents the analysis of gaps and opportunities. Section 5 briefly introduces the concepts' definitions that are used on the document. Section 6 presents the gaps, goals, barriers and opportunities recognized at the international level, organized by digitalization use classes (as defined in Chapter 1). Section 7 presents an overview of policies from three of the key countries recognized in Chapter 1, which are exemplary policies that promote digitalization. Based on the above, Section 8 presents the analysis of gaps, goals, barriers and opportunities for the case of Chile, also organized by digitalization use classes. Emphasis is put on the recognition of barriers that are particular for the context of Chile, as well as those from the international analysis that also apply to our country. This section also includes the analysis of three national actors that have been recognized as important players in digitalization at the national level. Section 9 presents a specific analysis of digitalization uses that involve and benefit citizens. Finally, Section 10 presents the potential contributions to future national policies that promote digitalization.

The report ends with a brief conclusion highlighting the main findings and recommendations.

The Annex includes the detailed map of uses developed in Chapter 1, as well as the association between digitalization applications and standards.

Chapter 1: State of the art

2 State of global developments

We are currently living under a technological revolution that has had an unprecedented impact on our way of life. The Digital Revolution, or third industrial revolution, has been fed with an ever-increasing advance in analogue and digital technologies, paving the way for the age of data and information. Even though several technologies have played a role in this transformation, the most recognizable keyword is "digital", usually associated with digital logic, computers, and developments such as the Internet. Although with humble beginnings, several technologies have enabled numerous uses, which in turn have transformed the way our society works.

The energy sector is one of the areas that has benefitted the most by this revolution. Although it is usually associated with technological advancements, the energy sector has seen an expansion in possibilities, transitioning from an industry of traditional services to a highly complex multi-actor system. Today, we hear about renewable energies, smart grids, prosumers, and many other terms that could not have been imagined without those technological advancements. Finally, it is widely recognized that information plays a key role in the development of new services and businesses, and data is an important component of these systems, as shown in Figure 1.

Chile has seen progress in the digital transformation, with several initiatives led by the public sector, ranging from the Digital Agenda 2020 launched in 2015 (Ministerio Secretaría General de la Presidencia, 2015), to the recent Law 21.180 for the government's digital transformation (Diario Oficial de la República de Chile, 2019), although the energy sector is not mentioned in such initiatives. Nevertheless, the Energy Policy 2050 recognizes the potential of several digitalization uses, such as smart grids, prosumers, demand response, among others (Ministerio de Energía, 2015). In addition, The Energy Route Map 2018-2022 specifically addresses energy modernization, also with several digitalization uses such as smart cities, smart grids, energy storage and energy efficiency (Ministerio de Energía, 2018). Even though the potential is clear, with a limited number of experiences already in practice in Chile, a comprehensive analysis of the state of the art in digitalization is still required. This analysis is crucial in the recognition of barriers and opportunities for our country in the digitalization of the energy sector.

This chapter provides the information required solve the aforementioned issues by presenting a comprehensive analysis of the state-of-the-art on digital revolution. It begins with the definition of key concepts and common terminology, followed by a review on digital transformation, including a detailed characterization of the most remarkable uses, classification and attributes. Then, a throughout review of standards associated with those uses is presented. Finally, a review of digitalization uses on key countries is presented.

2.1 *Definitions*

There are several definitions associated with the concept of digital transformation. Indeed, according to (P. C. Verhoef et al., 2019), we can recognize several stages in digital transformation, where some commonly found terms in literature are defined as follows:

- **Digitization** is "the encoding of analog information into a digital format (i.e., into zeros and ones) such that computers can store, process, and transmit such information."
- **Digitalization** "describes how IT or digital technologies can be used to alter existing business processes. For example, the creation of new online or mobile communication channels that allow all customers to easily connect with firms, and which change traditional firm-customer interaction."
- **Digital transformation** is "the most pervasive phase and describes a company-wide change that leads to the development of new business models, which may be new to the focal firm or industry."

Although digitization refers to the encoding process, it has been also used as a synonym for digitalization. Even though the terms of reference of the project call for a review of "Energy Digitization", for the purposes of this review, all development stages are under consideration.

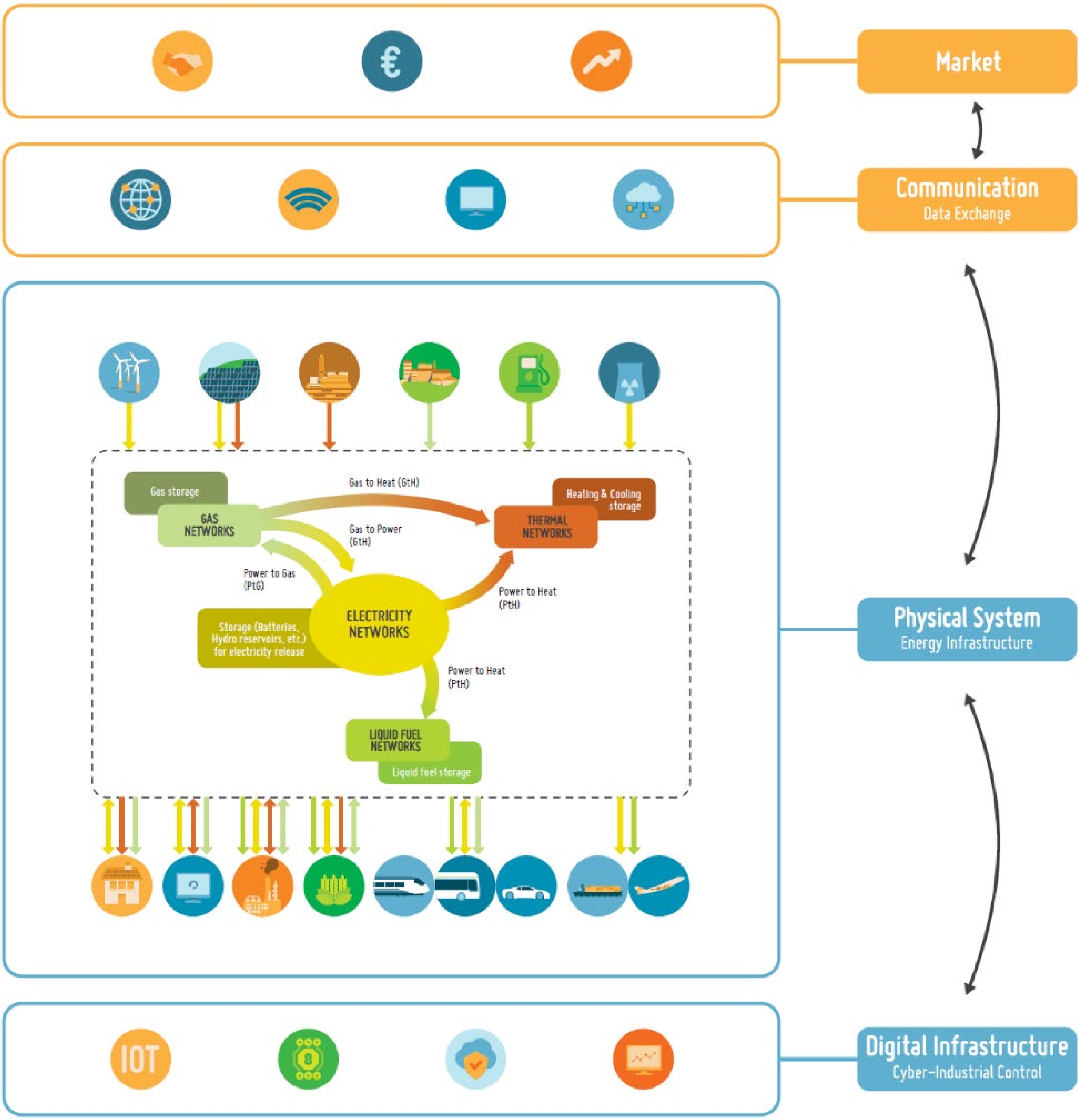

Figure 1: "The 4 layers of integrated energy systems" according to ETIP SNET Vision 2050 (ETIP SNET, 2018)

On the other hand, according to the International Energy Agency (IEA), digitalization has three fundamental elements (IEA, 2017, 2019):

- **Data**: digital information.
- **Analytics**: computing vast amounts of data to produce actionable insights.
- **Connectivity**: exchange of data between machines or humans and machines, through digital communications networks.

While data is mostly associated with digitization, connectivity and analytics are at the core of digitalization. However, advances are needed in all three elements (IEA, 2017).

The digital revolution is happening in all sectors, although some applications of digital technologies are more evident to end users than other (i.e., smart phone apps). The energy sector in particular has the big challenge of moving towards a consumer-centric (or end-user-centric) paradigm, taking advantage of the opportunities given by digitalization (*JRC Publications Repository: SETIS Magazine: Digitalisation of the Energy Sector*, n.d.). The following section presents a characterization of the the digitalization uses in several sectors that are associated or have an impact on energy.

2.2 Characterization, classification and attributes of digitalization uses

Being historically an early adopter of digital technologies (IEA, 2017, 2019), the energy sector has been recognized for its advances in digital transformation. Concepts such as Smart Grids are well established, with numerous international initiatives such as the former European Technology Platform for Smart Grids, today ETIP SNET[1], and popular scientific conferences devoted to this topic, such as the IEEE Innovative Smart Grid Technologies conferences[2] held since 2010 in North America (ISGT-NA), Europe (ISGT-Europe), Latin America (ISGT-LA) and Asia (ISGT-Asia).

However, the advancement of digital technologies has demanded increased agility from the energy sector that has only a "moderate level of digitalization" in some areas like utilities (Hitachi Social Innovation, 2020). Several applications that have been proposed for more than ten years are not yet mature or mainstream. The Council of European Energy Regulators has recognized several barriers and risks, as well as key smart grid technologies for the digitalization of the energy sector (Council of European Energy Regulators, 2019): smart meters, blockchain, electric vehicles, and batteries. This report concludes that the pathway “is to allow consumers (directly or through their intermediaries) to use innovative technology to be rewarded for changing their behaviour in a way that benefits the electricity system. At the same time, DSOs will be able to play an even more active role in managing the generation, load and electricity transport in their networks.” (Council of European Energy Regulators, 2019)

It has been recognized by the US Department of Energy (US Department of Energy, 2018) that advances in technology are required in this sense, identifying key digital transformations that need to be developed, such as storage technologies, cybersecurity and resilient and adaptive control systems. These and several other technologies have been gathered in this review of the state of the art and are characterized and categorized below.

New technologies and uses associated with the digitization of the energy sector can occur in multiple sectors, covering a wide spectrum of applications ranging from Smart farming to Virtual Power Plants. To recognize and determine the main needs

[1] https://www.etip-snet.eu/

[2] https://ieee-isgt.org/

and potencial uses of digitization in the energy sector in Chile, an exhaustive analysis of the uses developed worldwide has been made. In this sense, this survey requires a structured description and a rigorous classification of the possible digital applications in the energy sector.

These differentiations between uses consider technical aspects such as the distribution and transmission of energy, as well as economic aspects such as billing. Therefore, part of this classification is the assignment to a sector. In addition to the relevant technologies for each use, other aspects are considered such as the need for regulation, forecasting of use, adoption in pioneering countries in digitization, among others. Figures 3 and 4 show different proposals for sectoral categorization and uses of enabling technologies for different digital applications in the energy field. The first shows applications in which digitization contributes to the energy sector in the different aspects that it considers (balance of the system, process optimization, customer orientation). The second shows the innovations associated with digitization in the energy sector indicating how and in what they do.

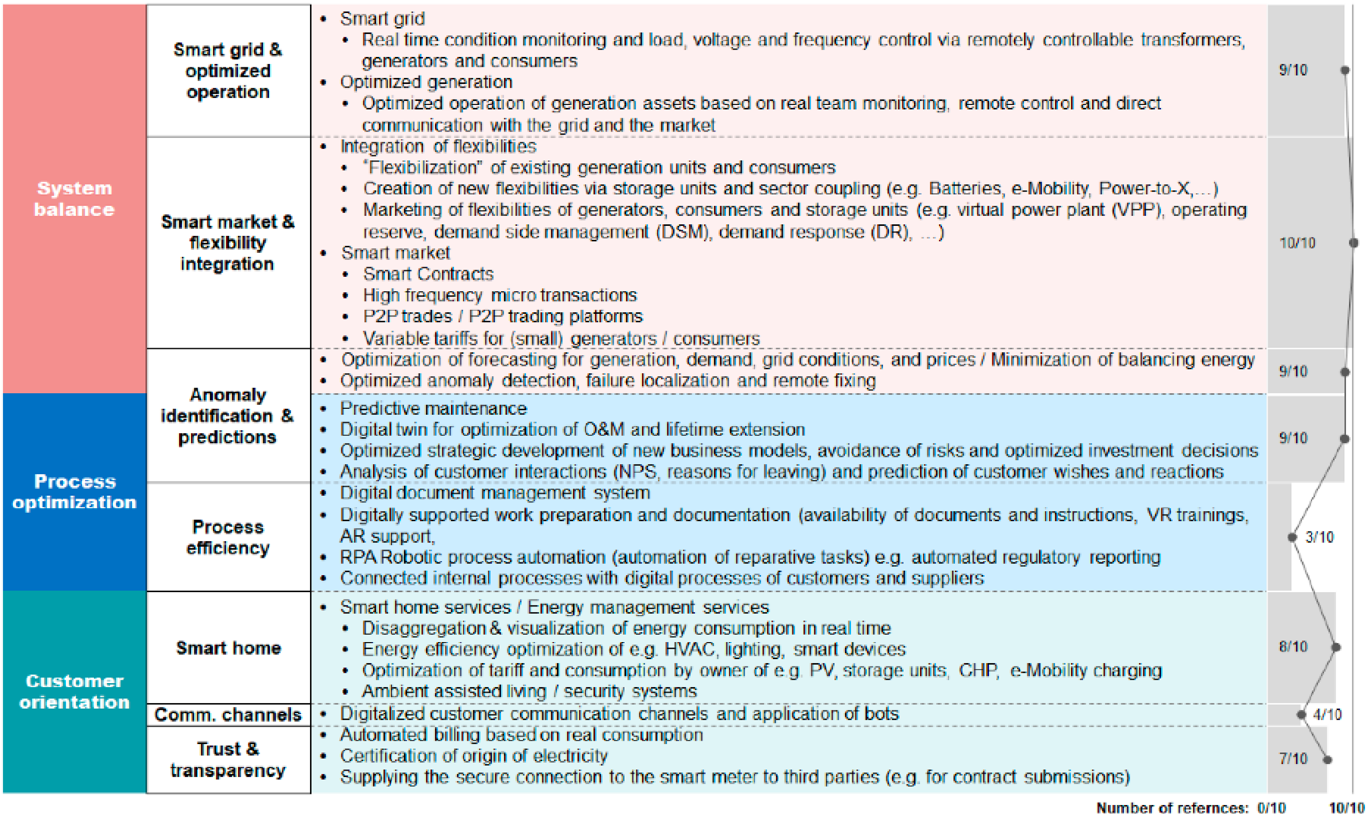

Figure 2: Digital applications in the energy sector; expected benefits attributed to the applications;and the impacted stakeholders (Weigel & Fischedick, 2019).

Although several reviewed articles (Andoni et al., 2019; Antonopoulos et al., 2020; Avancini et al., 2019; Chen et al., 2020; Dileep, 2020; Ford et al., 2017; Hossain et al., 2019; Pettifor & Wilson, 2020; Reka & Dragicevic, 2018; Sovacool & Furszyfer Del Rio, 2020; Wang et al., 2019; Weigel & Fischedick, 2019) refer to numerous uses related to digitalization, two distinct categories can be identified:

- **Enabling Technologies**: related to tangibles such as equipment or machinery, but also techniques and methods.
- **Applications**: related to uses of those technologies to face a challenge or solve a particular problem.

For example, in Figure 4 an application of optimal pricing for electric vehicle charging is shown, where several technologies are used, such as geolocation services (e.g. GPS), EV charging stations and blockchain ledger. Several technologies and applications have been gathered from the literature review, and those are presented at large in the annex, and in a summarized version in the next sections.

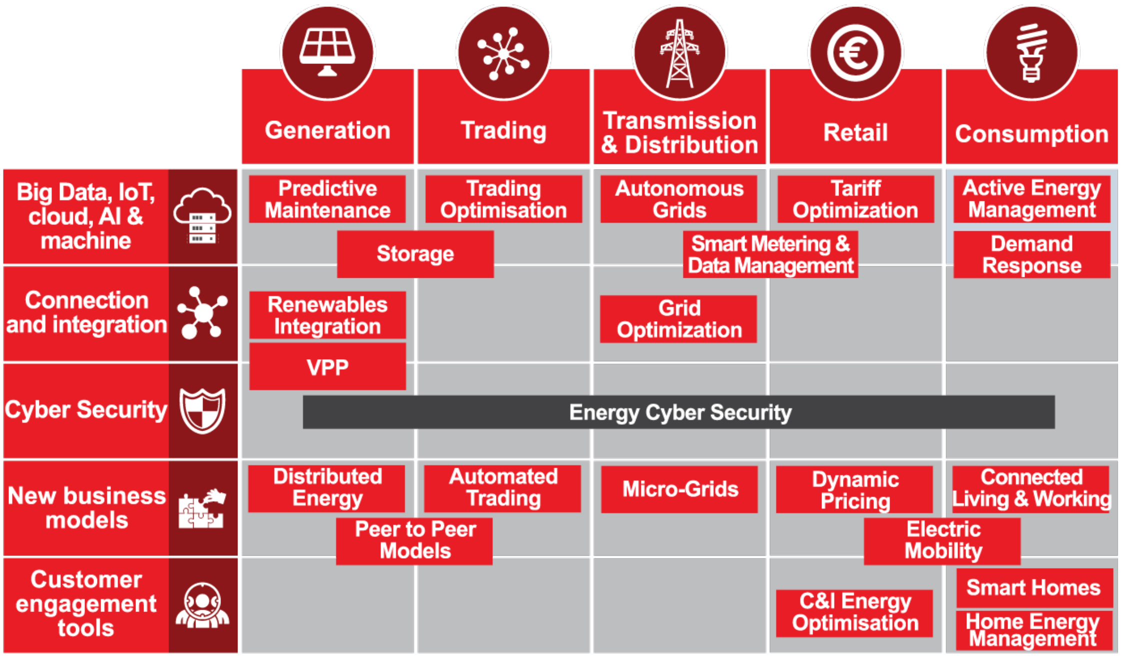

Figure 3: Digital Energy Innovation Hotspots. Source: (Hitachi, n.d.)

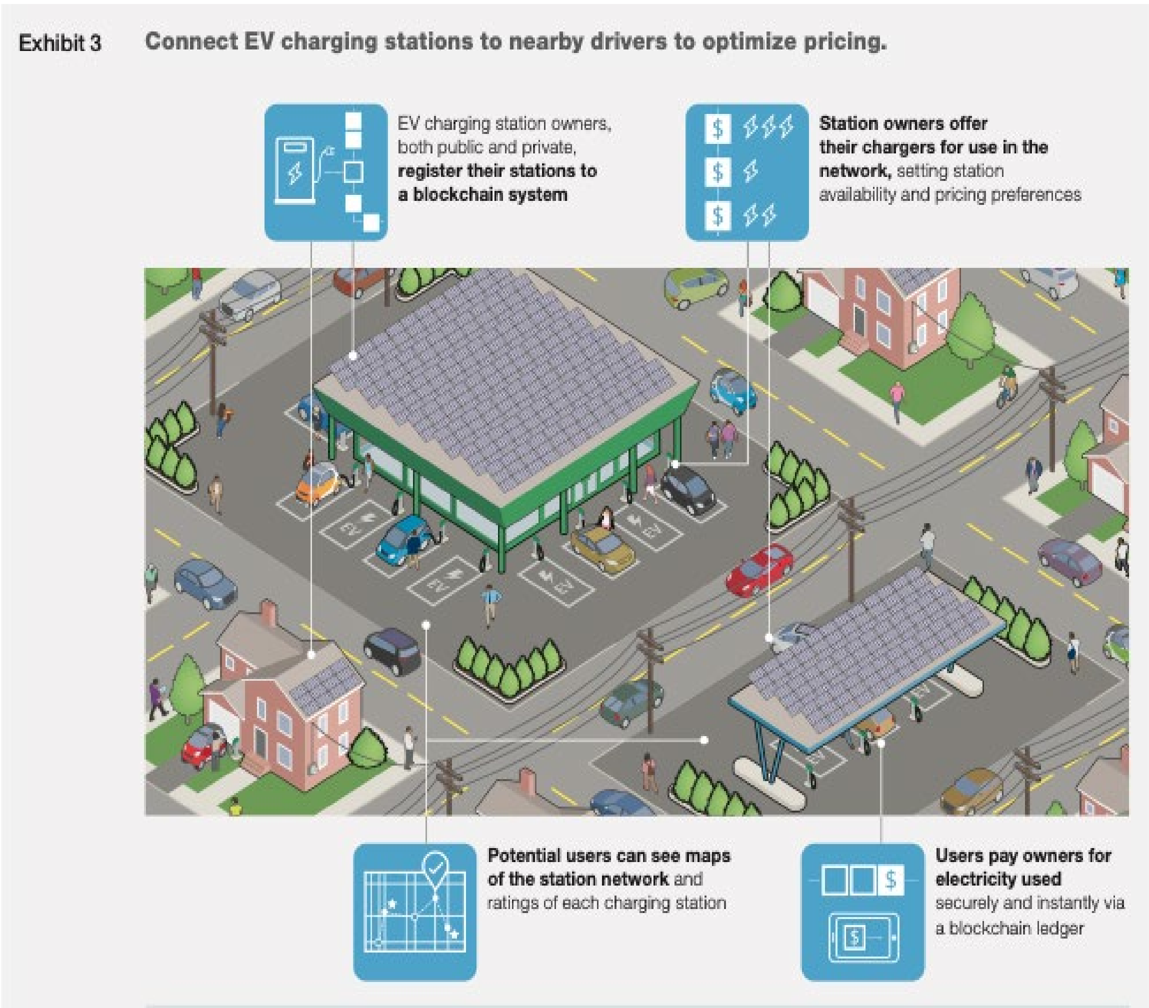

Figure 4: Example of application and technology associated with digitalization. Source: (McKinsey & Company, n.d.)

2.2.1 *Digitalization Applications*

Six sectors have been selected to categorize digital uses and applications that have an impact on the energy sector, which are listed below: (Ministerio de Energía, 2020)

- **Transportation**
- **Industry**
- **Buildings (residential, commercial)**
- **Electricity generation, including transmission and distribution of electricity**
- **Finance**
- **Public sector**

On the other hand, the following classes are distinguished, which are a result of grouping uses and applications that are related to each other (according to the gathered uses) or are associated under "umbrella" concepts in the literature:

- **Smart grid:** Smart grid is a cyber-physical system which includes communication system with the power flow structure, to gain intelligence and automated control. The communication support schemes and real-time measurement techniques of smart grid enhance resiliency and forecasting as well as offer protection against internal and external threats.
- **Distributed Energy Resources (DER) management:** It alludes to the way in which the energy resources distributed in the electrical network are managed, seeking that said management efficiently take advantage of the availability of resources according to the conditions in which the system is found.
- **Customer domain:** This class contains the uses whose focus is on the end user and how this participates in the system, considering aspects such as billing or the existence of the prosumer as a relevant agent for the energy system.
- **Process management:** This class is associated with uses whose objective is to improve processes associated with energy generation and / or consumption and also for internal processes.
- **Mobility:** It includes those mobility applications that have incorporated digital technologies in some of their processes. Incorporation of mobility is important as transportation and electromobility are closely associated with energy.
- **Data management:** Uses oriented to data analysis using Smart Meters and / or AMIs. These uses allow to have a more reliable network for the information and forecasts that they deliver.
- **Smart city:** Smart City is a vision of future urban area where smart ICT technologies will connect every major sector of the city through rich features such as the smart economy, smart mobility, smart environment, smart people, smart living, and smart governance.

Table 1 presents a summary list of selected uses and applications (Adler et al., 2019; Barai et al., 2016; Chen et al., 2020; Choudhary & Umang, 2015; Dileep, 2020; Hewlett Packard Enterprise, n.d.; Hossain et al., 2019; IEA, 2017; *ISO 8373:2012(En), Robots and Robotic Devices — Vocabulary*, n.d.; Jiang et al., 2004; Koirala et al., 2018; Lampropoulos et al., 2013; Lv et al., 2018; Mariano-Hernández et al., 2021; Mehigan et al., 2018; Mobley, 2002; Murthy Balijepalli et al., 2011; Nguyen et al., 2018; Parhizi et al., 2015; Sikder et al., 2018; Weigel & Fischedick, 2019; Zafar et al., 2020; Zhang et al., 2019), along with a brief description of each one.

Table 1: Summary of digitalization uses and applications

Class	Uses & applications	Definition / Description
Smart grid	Smart substation	Conventionally, a substation employs circuit breaker (CB), protection relays, voltage transformers (VTs) and current transformers (CTs), which are wired collectively, using copper cables. This is now changing to what is known as the smart substation, in which the workstations, protection devices, and low-level transducers are connected together on an optical fiber communications backbone.

Class	Uses & applications	Definition / Description
	Feeder automation	FA is the ability to monitor and control the distribution network remotely, to collect and provide information to consumers in a useful manner.
	Microgrids	A group of interconnected loads and distributed energy resources (DERs) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid to enable it to operate in both grid-connected or island modes.
DER management	Demand Side Management (DSM) / Demand Response (DR)	DSM refers to a series of policies and measures that range from long-term energy efficiency policies and incentive rates, to real-time control of distributed energy resources. DR is defined as changes by end customers from their normal electricity consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce less use of electricity at times of high wholesale market prices or when system reliability is compromised.
	Energy storage	Energy storage is defined as the conversion of electrical energy from a power network into a form in which it can be stored until converted back to electrical energy. Energy storage technologies include flow batteries, ultracapacitors, flywheels, pumped-hydro, super-conducting magnetic energy storage and compressed air.
	Virtual Power Plant (VPP)	By means of advanced information communication technology and software system, DER can be integrated and dispatched harmonically via VPP concept which is to participate in operation of the system and the electricity markets as a special power plant.
	Distributed energy (electricity/DG & gas)	Distributed energy corresponds to those energy production applications at or near the point of consumption, which may or may not be connected to the distribution system.
Customer domain	Prosumer & P2P trades	Prosumer means generator and consumer, e.g., household with photovoltaic units. Peer-to-peer energy (P2P) trading is the buying and selling of energy between two or more grid-connected parties
	Retailing, billing & customer orientation	Retailing: Retailers trade power to consumers and may aggregate or broker DER between market or consumers in the future. Most are connected to a trading organization to allow participation in the wholesale market. Billing: Managing consumer billing information, sending billing statements, and processing received payments. Customer orientation applications use a variety of digital technologies and mostly aim at providing a benefit to the customer, which in some cases could be monetized by the service provider. These applications offer additional benefits to the user and increase revenues.
Process management	Process optimization & automation (gas, oil & coal)	Besides supporting the balancing of the energy system, digital applications offer great potential to optimize internal processes. Some of the process optimizations are specific to the energy sector while others can be observed across different sectors (Data Analytics, Digital Twins, Predictive Maintenance or Robotic Process Automation are some examples).

Class	Uses & applications	Definition / Description
	Emission monitoring	Emission monitoring refers to detecting, measuring, and avoiding methane emissions. It aims to provide effective monitoring and quantification of emission levels at low cost. This is done through the integration of digitized devices and the analysis of data for the development of parametric and predictive monitoring systems.
Mobility	Transportation for personal use	It is related to the incorporation of digital technologies and electricity in transport for personal use (vehicles, bicycles, motorcycles, scooters, among others). *Application cases: Navigation software (Waze), Electric vehicle related applications (V2G services, Smart charging station, P2P charging network market), Advanced driver-assistance systems (ADAS).*
	Public transport	In this context, it refers to the incorporation of digital technologies and electricity in public transport in all its forms (bus, airline, train, ferry, among others). *Application cases: Demand simulator, Fleet monitoring, Dynamic routing, Smart payment systems, Smart charging scheduling, IA cameras, V2X services*
	Transport cargo	It refers to the incorporation of digital technologies and electricity in the commercial transport systems of goods or products. *Application cases: Smart logistics, Smart routing, Fleet monitoring, V2X services.*
	Shared mobility	Shared mobility refers to the shared use of electric or non-electric means of transport (vehicles, bicycles, among others), according to the needs of the users. *Application cases: Fleet monitoring, Ride sharing/hailing platforms (Uber, Cabify, etc.), Station-based vehicles (Itaú bikes), Free floating (Awto, Mobike, etc), Mobility as a service.*
Data management	Predictive maintenance	Predictive maintenance is a condition-driven preventive maintenance program. Predictive maintenance uses direct monitoring of the mechanical condition, system efficiency, and other indicators to determine the actual mean-time-to-failure or loss of efficiency for each machine-train and system in the plant.
	Forecasting and predictive analytics	Forecasting is a technique that uses historical data as inputs to make estimates that are predictive in determining the direction of future trends. Predictive analytics is the use of advanced analytic techniques that leverage historical data to uncover real-time insights and to predict future events.
Smart city	Smart lighting	Smart lighting refers to lighting designed for energy efficiency, providing comfort and without neglecting safety. It usually consists of high-efficiency systems, controllers and sensors, in order to manage lighting considering the occupation and the presence of natural light.

Class	Uses & applications	Definition / Description
	Smart traffic	Smart traffic refers to the improvement of vehicular traffic flow using traffic signals and status data (number of vehicles and pedestrians), in addition to keeping travelers informed about the next bus or train in real time through the use of digital signage.
	Smart home & building	A smart home & building is a dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed.
	Smart industry	Smart industry seeks to allow easier tracking of transport and logistics flows. It also involves the automation of industrial processes and manufacturing.
	Smart farm	The smart farm aims to improve water utilization and irrigation by taking advantage of weather forecast and agricultural data, key trends and anomalies, and evapotranspiration index.
	Smart parking	Smart parking is a system that allows energy saving and the delivery of information in real time to users in order to minimize waiting and circulation times.
	Smart waste management	Smart waste management refers to the use of sensors and connectivity between garbage containers to monitor the level of garbage inside and improve collection routes, in order to generate cost savings, reduce C02 emissions from trucks and increase in the satisfaction of citizens.
	Smart fleet management	Fleet management addresses several specific challenges of controlling fuel and maintenance expenses, driver and passenger safety, and providing good customer service. IoT provides opportunities to improve fleet performance and customer satisfaction. Smart cities can employ fleet management solutions to manage the vehicles in their fleet more efficiently and analyze the causes of traffic congestion through the data captured by those vehicles.
Other	Market management & operation	Market managers include independent system operators (ISOs) for wholesale markets and forward markets in various ISO/regional transmission organizations (RTOs) regions. There are services, transmission and DR markets as well. Market Operators help in smooth functioning of market. Functions include price quotation streams, balancing, audit, financial and goods sold clearing, and more.
	Ancillary services	Provide a market to provide spinning reserve, voltage support, frequency support, and other services. Through these ancillary services, the aim is to give greater stability and robustness to the network.
	Energy management	Energy management functions may include in IHDs (In Home Displays) to inform the consumer about energy cost and usage, responsiveness to price signals on the basis of consumer-entered preferences, set points that limit utility or local control actions to a consumer specified band, control of loads without continuing consumer involvement, and consumer over-ride capability. It includes the connection of thermostats in buildings or sophisticated heating, ventilation and air conditioning (HVAC) management systems in homes, offices, public buildings and shopping centers.

Class	Uses & applications	Definition / Description
	Operation (monitoring/control/reporting)	Monitoring: Supervises network topology, connectivity and loading conditions, including breaker and switch states, as well as control equipment status. Control: Supervise wide area, substation and local; carry out automatic or manual control. Reporting: Operational statistics and reporting roles, archive online data, and perform feedback analysis about system efficiency and reliability.
	Teleworking	Telework refers to the use, by employees, of information and communication technologies (ICTs) to work from home, in telecentres or in other places.

Based on the review of these applications and uses, Table 2 presents their association to the six sectors listed above. Also we include the main type of energy that could be affected due to these digital applications. For example, Smart substation is a specific application of electricity generation sectors and only affect the use of electricity; digital application to process optimization can reduce electricity and fossil fuels (natural, coal, diesel, etc.) in a industry; digital application for transportation for personal use can reduce fossil fuels (gasoline, diesel) and electricity for electric vehicles.

Table 2: Digitalization uses and applications associated with sectors

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Smart substation		X		X			Electricity
Feeder automation				X			Electricity
Microgrids	X	X	X	X		X	Electricity
DSM/DR	X	X	X	X		X	Electricity
Energy storage	X	X	X	X		X	Electricity
VPP		X	X	X			Electricity
Distributed energy (electricity/DG & gas)		X	X	X		X	Electricity
Prosumer & P2P trades		X	X	X			Electricity and fossil fuels
Retailing, billing & customer orientation	X			X	X	X	Electricity and fossil fuels
Process optimization & automation (gas, oil & coal)	X	X	X	X			Electricity and fossil fuels
Emission monitoring		X		X			Fossil fuels
Transportation for personal use	X		X				Fossil fuels and electricity
Public transport	X						Fossil fuels and electricity
Transport cargo	X						Fossil fuels and electricity
Shared mobility	X						Fossil fuels and electricity
Predictive maintenance	X	X	X	X		X	Electricity and fossil fuels
Forecasting and predictive analytics	X	X	X	X	X	X	Electricity and fossil fuels
Smart lighting		X	X			X	Electricity
Smart traffic	X	X				X	Electricity and fossil fuels
Smart home & building		X	X				Electricity and fossil fuels
Smart industry		X			X	X	Electricity and fossil fuels
Smart farm		X					Electricity and fossil fuels
Smart parking	X					X	Fossil fuels and electricity
Smart waste management		X	X			X	
Smart fleet management	X	X				X	Fossil fuels and electricity
Market management & operation				X	X		

Uses & Applications	Transportation	Industry	Buildings	Electricity generation	Finance	Public Sector	Main type of energy
Ancillary services	X	X	X	X			Electricity
Energy management	X	X	X	X			Fossil fuels and electricity
Operation (monitoring / control / reporting)				X			Electricity
Teleworking	X	X	X	X		X	Fossil fuels and electricity

2.2.2 *Enabling Technologies*

There are several technologies necessary for the incorporation of possible digital uses and applications in the energy sector, which we will call "enabling technologies", described in Table 3. The technologies collected in the review, associated with the list of uses and applications, are found in Table 4.

Table 3: Summary of enabling technologies

Category	Enabling technology	Definition
Smart home & Smart building (Ford et al., 2017; IEA, 2017)	Load Monitor	Monitoring of loads through instruments connected to the supply of the studied unit.
	In home display	Electronic device that displays on screen the energy consumption of the home in which it has been installed.
	Smart thermostat	Smart thermostats is a device that allows consumer remotely to control the temperature and HVAC system in their homes with a smart phone or other device.
	Smart light	Smart light refers to the most efficient use of light, including intelligence in its on and off through sensors and connection between the different bulbs that make up the network.
	Smart plug/switch	Smart plug is a device that seeks to configure and control devices that work connected with a cable, once the smart plug is connected to the outlet, it manages the devices connected to it through instructions received via Wi-Fi.
	Smart appliance	A smart appliance is understood as an appliance that can be controlled remotely and/or automatically based on external signals that indicate when it should work, without neglecting user preferences.
	Hub	A hub is a device whose objective is to be the connection point for the devices that make up a network (generally LANs).
Smart Grid (Dileep, 2020; IEA, 2019; Nguyen et al., 2018; Reka & Dragicevic, 2018)	Smart meters	Smart meters are powerful tools which fundamentally change the operation of power grids. In addition to performing the functions of a traditional meter, smart meters can be used as sensors across the entire distribution grid. When an Advanced Metering Infrastructure (AMI) is in place, smart meter can measure and record actual power usage during a day at certain time interval.
	AMR/AMI	AMI is the system to add the communication link to the smart grid network. AMI includes bidirectional data flow between end users and utilities. AMI provides intelligent management, better maintenance, easier and proper additions and replacement of utility assets which results in better power quality. AMI consists of three basic components: smart metering devices at the user end, two-way communication path between end user and utility, and automated software and operation center for data processing. AMR means advanced meter reading; this

Category	Enabling technology	Definition
		technology focuses on reading meters automatically and transferring it to the network operator for later use.
	V2G	V2G means Vehicle-to-grid, this enabling technology refers to the use of electric vehicles as a distributed resource of the electric grid.
	EV/PHEV	PHEV means Plug-in hybrid electric vehicles, corresponds to vehicles that use batteries and some other alternative fuel. EV means electric vehicle, correspond to vehicles that use electric motors for their operation, so they do not use other fuels such as oil.
	IED (relays, SCADA, RTU, etc.)	IEDs are intelligent electronic devices, these devices are responsible for monitoring and protecting different equipment from control mechanisms.
	PMU	Phasor measurement units are aimed at calculating the magnitude and angle of an electrical phasor in the network.
	WAMS	Wide-area monitoring systems seek to improve situational awareness and visibility within the electrical system, in addition to maintaining its stability from the measurement and analysis of information from a wide-area electrical network.
IoT & IoE (Economic Commission for Latin America and the Caribbean, 2018; Nguyen et al., 2018)	Smart Sensors	Device that senses data (input) from its environment, and from them performs functions based on the information extracted from data processing.
	Sensor and actuator networks	It is a network of sensors that collect information from their environment and actuators that respond to the information delivered by the sensors through the interaction that the network allows.
	LAN/HAN/NAN/WAN	LAN: Local Area Network. HAN: Home Area Network. NAN: Neighborhood Area Network. WAN: Wide Area Network.
	Cloud	It is a model for allowing ubiquitous, convenient, and on-demand network access to a number of configured computing resources (e.g., networks, server, storage, application, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.
	5G	Fifth generation mobile network for cellular networks.
Big data, machine learning & AI (Antonopoulos et al., 2020; Economic Commission for Latin America and the Caribbean, 2018; Hossain et al., 2019; IEA, 2019)	Machine learning	AI application in charge of giving systems the ability to learn from their data, without being explicitly programmed.
	Data mining	Process for extracting usable information from a dataset with raw data. Analyze the patterns using different algorithms and tools such as clustering.
	Nature inspire intelligence	Models and/or algorithms for solving problems built from observing the behavior of naturally occurring phenomena
	Artificial Neural Networks (ANN)	Artificial neural network (ANN) is a computational model that consists of several processing elements that receive inputs and deliver outputs based on their predefined activation functions
	Multi-agent systems	It is a computational system composed of multiple intelligent agents that interact with each other. It is part of the field of distributed artificial intelligence (DAI) and its agents have the properties of autonomy, social capacity, reactivity and proactivity, in addition, agents can be static (permanently located in some computer) or mobile (move through the computer network, such as the Internet)
	Clustering	Clustering is a set of samples that have no class labels, that from some algorithm (called clustering algorithms) are labeled in some class. According to a criterion, the similarity between the samples is measured, and then the similarity is divided into several subsets, so that the similar samples can be classified into one class, and the dissimilarity samples are divided into different classes.

Category	Enabling technology	Definition
	Natural language processing (NLP)	Combines linguistics and AI so that computers understand the input of human or natural language.
	Digital twin	The digital twin is a comprehensive digital representation of an individual product. It includes the properties, condition and behavior of the real-life object through models and data.
	Autonomous Vehicle	An autonomous car is a vehicle capable of sensing its environment and operating without human involvement. A human passenger is not required to take control of the vehicle at any time, nor is a human passenger required to be present in the vehicle at all. An autonomous car can go anywhere a traditional car goes and do everything that an experienced human driver does.
Ledger	Blockchain (Andoni et al., 2019; Economic Commission for Latin America and the Caribbean, 2018)	Blockchain technology is decentralized and peer to peer communication. It is also publicly available like a digital ledger. It can be applied to stored data or transaction in a trusted environment without the third-party involvement. It is a public distributed database which holds the encrypted ledger. Blockchain is technology in a global database that anyone, anywhere, with an internet connection, can use.
Physical action (IEA, 2019)	Actuators	A device responsible for generating a movement in a mechanism or system.
	3D Printers	3D printing is an additive manufacturing method that can build objects directly from a computational model.

Table 4: Enabling technologies for each Use/application

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA, RTU, etc.)	PMU	WAMS	Smart Sensors	Sensor and actuator networks	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire intelligence	Artificial Neural Networks (ANN)	Multi-agent systems	Clustering	Natural language processing (NLP)	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Smart substation								x	x			x	x	x			x														
Feeder automation									x			x	x	x			x														
Microgrids								x	x	x	x	x	x		x	x	x	x													
DSM/DR			x		x	x		x	x					x			x	x													
Energy storage											x					x	x			x											
VPP																x	x	x		x											
Distributed energy (electricity/DG & gas)																		x													x
Prosumer & P2P trades								x									x												x		
Retailing, billing & customer orientation																				x	x	x			x	x					
Process optimization & automation (gas, oil & coal)															x		x	x		x	x		x	x			x	x		x	x

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA, RTU, etc.)	PMU	WAMS	Smart Sensors	Sensor and actuator networks	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire intelligence	Artificial Neural Networks (ANN)	Multi-agent systems	Clustering	Natural language processing (NLP)	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Emission monitoring															x		x	x		x			x		x						
Transportation for personal use										x	x																	x			
Public transport										x	x																	x			
Transport cargo											x																	x			
Shared mobility										x	x									x						x	x	X			
Predictive maintenance								x	x			x		x						x							x				
Forecasting and predictions																				x	x		x		x						
Smart lighting		x		x											x	x	x		x											x	
Smart traffic									x																						
Smart home & building	x	x	x	x	x	x	x	x							x		x	x	x	x											
Smart industry						x									x			x		x	x				x			x			x
Smart farm			x	x	x			x							x		x	x	x	x	x				x					x	
Smart parking								x							x		x	x	x	x											

Technologies	Load monitor	In home display	Smart thermostat	Smart light	Smart plug/switch	Smart appliance	Hub	Smart meters	AMR/AMI	V2G	EV/PHEV	IED (relays, SCADA, RTU, etc.)	PMU	WAMS	Smart Sensors	Sensor and actuator networks	LAN/HAN/NAN/WAN	Cloud	5G	Machine learning	Data mining	Nature inspire intelligence	Artificial Neural Networks (ANN)	Multi-agent systems	Clustering	Natural language processing (NLP)	Digital twin	Autonomous vehicle	Blockchain	Actuators	3D printers
Uses / Applications	Smart home & Smart building							Smart grid							IoT & IoE					Big data, machine learning & AI										Physical action	
Smart waste management		x													x		x	x	x	x										x	
Smart fleet management										x	x				x		x	x	x	x								x			
Market management & operation																			x	x									x		
Ancillary services	x											x	x	x	x	x	x	x	x											x	
Energy management	x	x						x	x						x		x	x	x	x										x	
Operation (monitoring, control, reporting)								x	x			x	x	x	x	x	x			x			x						x	x	
Teleworking		x															x	x	x								x				x

It can be seen from this analysis that the IoT technology category is the one that appears the most across uses. On the other hand, uses related to consumer domain are the ones that use machine learning, big data and AI most often. As expected, Smart grid uses are closely associated with smart grid enabling technologies. Finally, uses associated with smart city require a variety of technologies.

2.3 Standards

Several authors have covered standards and norms related to digitalization, ranging from smart grid and cybersecurity (Leszczyna, 2018; Nafi et al., 2016), IoT (Kassab & Darabkh, 2020), smart meters (Kabalci, 2016) and EVs (Das et al., 2020). However, the most comprehensive list of standards was developed by NIST (Song et al., 2014) focusing on testing and certification for Smart Grids. The association of uses and standards is provided in the Annex, from this association the most relevant standards for the uses and applications described in this document can be identified. A summary of the most relevant standards or standards family is provided in Table 5.

Table 5: Relevant standards for digitalization of the energy sector

Standard or Family	Description	Related uses
ANSI/CEA 709	By the end of the 1990s, LON (Local Operating Network) was standardized by the Consumer Electronics Association (CEA) under the title "Control Network Protocol" as CEA-709.	Smart substation, Feeder automation, DER management DSM/DR, Energy management Operation, Distributed energy, Predictive maintenance, Smart lighting, Smart traffic, Smart home & building, Smart industry.
IEC 61000	The structure of the IEC 61000 series reflects the subjects dealt with by basic Electromagnetic Compatibility (EMC) publications. They include terminology, descriptions of electromagnetic phenomena and the EM environment, measurement and testing techniques, and guidelines on installation and mitigation.	Smart substation, Feeder automation, Market management & operation, Microgrids, DER management, Energy storage Ancillary services, Energy management, Retailing, billing & consumer orientation, Operation, Distributed energy, Mobility (class)
IEC 61850	IEC/TR 61850 is applicable to power utility automation systems and defines the communication between intelligent electronic devices in such a system, and the related system requirements.	Feeder automation, Market management & operation, DER management, DSM/DR Energy storage, VPP, Ancillary services, Energy management Retailing, billing & consumer orientation, Operation, Distributed energy, Electromobility, Smart home & building, Smart industry
IEC 61970	The IEC 61970 series of standards deals with the application program interfaces for energy management systems (EMS).	Smart substation, Feeder automation, Market management & operation, Microgrids DER management, DSM/DR Ancillary services, Energy management, Operation, Distributed energy.
IEC62325	IEC 62325 is a set of standards related to deregulated energy market communications, based on the Common Information Model.	Smart substation, Market management & operation, DER management, VPP, Retailing, billing & consumer orientation, Operation, Distributed energy, Forecasting and predictions, Smart home & building.

Standard or Family	Description	Related uses
IEEE 1901	A standard for high-speed communication devices via electric power lines, so called broadband over power line (BPL) devices, is defined. All classes of BPL devices can use this standard, including BPL devices used for the first-mile/last-mile connection to broadband services as well as BPL devices used in buildings for local area networks (LANs), Smart Energy applications, transportation platforms (vehicle) applications, and other data distribution.	Smart substation, Feeder automation, DER management DSM/DR, Energy storage, Energy management, Operation, Distributed energy, Mobility (class), Smart home & building, Smart industry.
IEEE 2030	IEEE 2030 provides best practices for achieving smart grid interoperability. It is the first all-encompassing IEEE standard on smart grid interoperability providing a roadmap directed at establishing the framework in developing an IEEE national and international body of standards based on cross-cutting technical disciplines in power applications and information exchange and control through communications. IEEE 2030 establishes the smart grid interoperability reference model (SGIRM).	Smart substation, Feeder automation, DER management DSM/DR, Energy management, Smart home & building, Smart industry.
IETF RFC-6272-2011	This standard provides Smart Grid designers with advice on how to best "profile" the Internet Protocol Suite (IPS) for use in Smart Grids. It provides an overview of the IPS and the key infrastructure protocols that are critical in integrating Smart Grid devices into an IP-based infrastructure.	Smart substation, Feeder automation, Market management & operation, Microgrids, DER management, DSM/DR, VPP, Ancillary services, Energy management, Retailing, billing & consumer orientation, Operation, Distributed energy, Electromobility, Smart home & building.
ISO/IEC 14908	This specification applies to a communication protocol for local area control networks. The protocol provides peer-to-peer communication for networked control and is suitable for implementing both peer-to-peer and master-slave control strategies.	Smart substation, Feeder automation, Market management & operation, Microgrids, DER management, DSM/DR, VPP, Ancillary services, Energy management, Retailing, billing & consumer orientation, Operation, Distributed energy, Mobility (class), Smart home & building

2.4 Key countries

The following countries have been identified as pioneers in digital transformation. From the list, all countries are placed on top of the BloombergNEF report "Industrial Digitalization: National Strategies and Ranking" (see Figure 5), except for Finland, which was suggested by the International Expert. The list includes examples of agencies, divisions or organizations in those countries that have a relationship with digital transformation. In addition, the uses and focuses of each country in terms of digitization of the energy sector are briefly described.

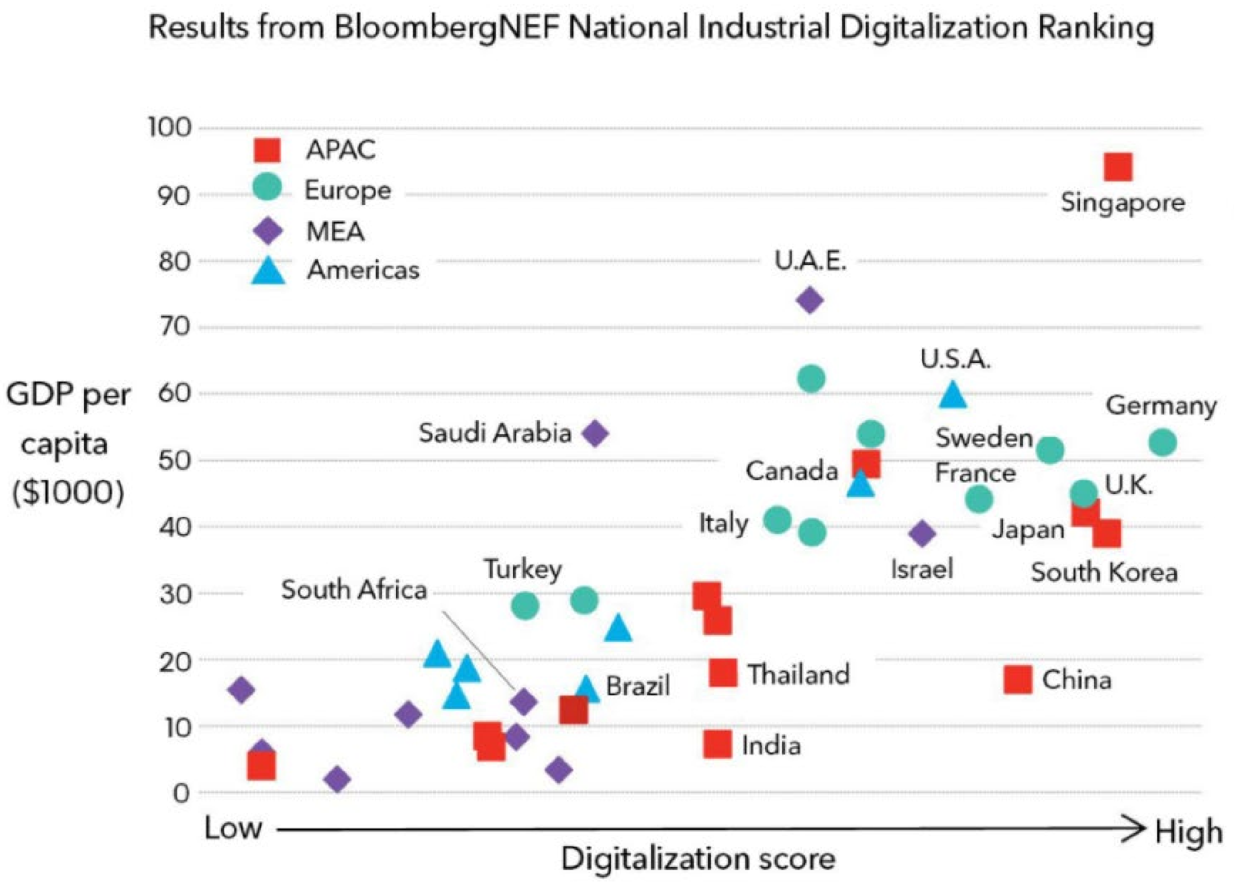

Figure 5: Industrial Digitalization: National Strategies and Ranking Source: (Bloomberg, 2019)

2.4.1 Germany

In Germany, digital transformation focused on business and politics is promoted, seeking the creation of value with new products, services and business models. Taking this into account, the BDEW develops an agenda (BDEW (Bundesverband der Energie- und Wasserwirtschaft), n.d.) where the most relevant concepts to achieve an effective transformation in said country are mentioned, some of the main axes of digitization in the case of Germany are shown in Figure 6.

In the aforementioned agenda there is a special emphasis on "Big Data" as a crucial technology for the digitization of the energy sector. Furthermore, considering digitization in the industrial sector, predictive maintenance, "Smart Metering" and -something further from machines- "process mining" is mentioned. On the other hand, moving away from the industrial sector, the use of "Virtual Power Plants" and demand management and forecasting are also mentioned, including concepts such as Real time Billing and prosumers, whose implementation is linked to concepts such as "Smart City" and " Smart Home".

In addition to the BDEW, the BMWi is also a participant in the digitization through the 10-step Digital Strategy 2025 (BMWI (Bundesministerium für Wirtschaft und Energie), n.d.), including smart networks, data security, digital education, among others. Also, there is a focus of BMVI on the areas of mobility (*BMVI - Automated and Connected Driving*, n.d.). Within this sector, the aim is to achieve, among other objectives outside the energy sector, a more efficient and sustainable transport system through automated vehicles, connected to each other (vehicle-to-vehicle) and connected to the infrastructure (vehicle-to-infrastructure).

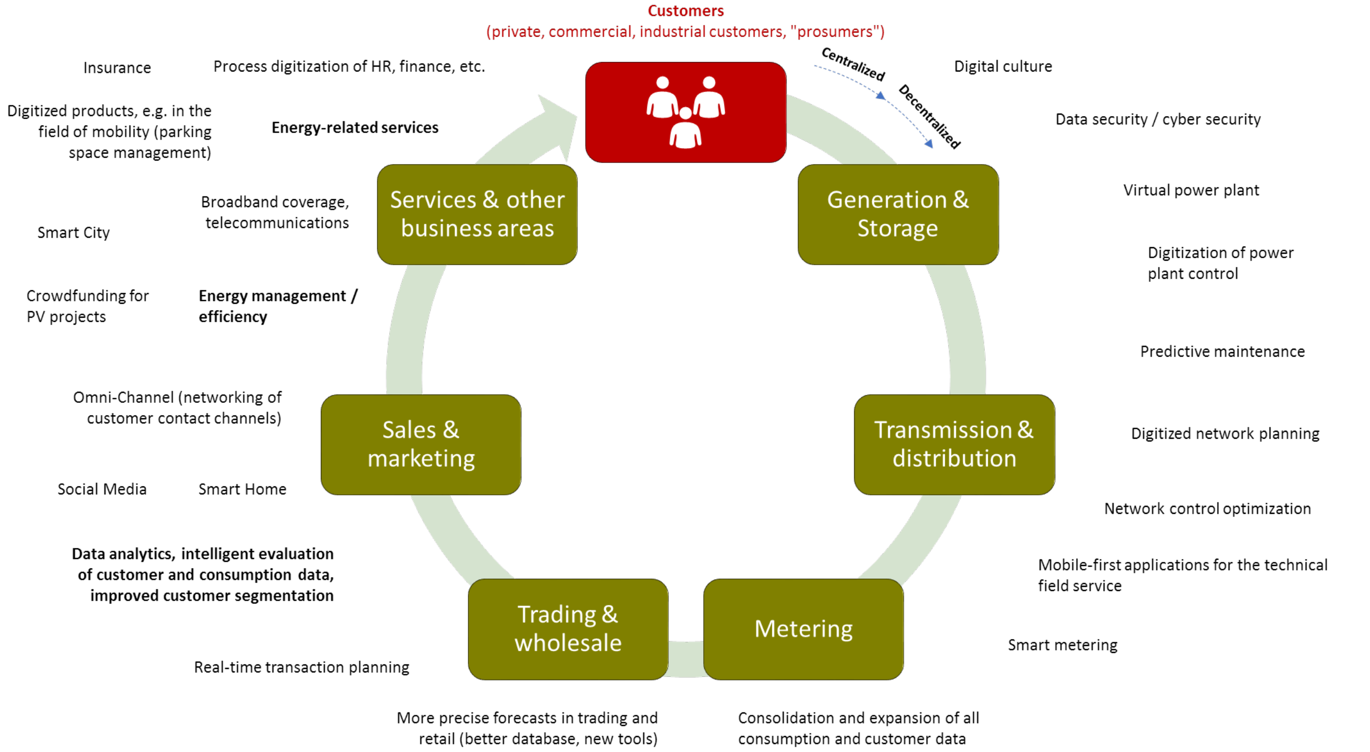

Figure 6: Digitization along the energy / value chain stages in Germany (Adapted from (BDEW (Bundesverband der Energie- und Wasserwirtschaft), n.d.)*)*

2.4.2 *Finland*

In the case of Finland, the main objective is to abandon the use of fossil fuels and increase the use of renewable energy. These objectives are used as the basis for its digitization project due to the new storage needs and flexibility of the network that this implies, to achieve this they work based on the concepts set out in Figure 7. In addition, the electrification of transport in the country led by the Ministry of Transport (*Digibarometer: Requirements and Use of Digitalisation in Finland Are High - Ministry of Transport and Communications*, n.d.).

The objectives and focuses of the program are found in (*Business Finland - Smart Energy Finland*, n.d.) and explicitly quoted are:

"- To support the international growth of companies and to attract international investments to Finland

- To contribute to the creation of a solid foundation for expertise with the development of smart energy ecosystems and test platforms.

- To challenge the energy sector into utilizing digitalization, IoT, artificial intelligence and the Internet of Energy

- To introduce new business concepts in the fields of energy efficiency, renewable energy, energy storage systems, smart networks and integration of steering as well as consumer-oriented business."

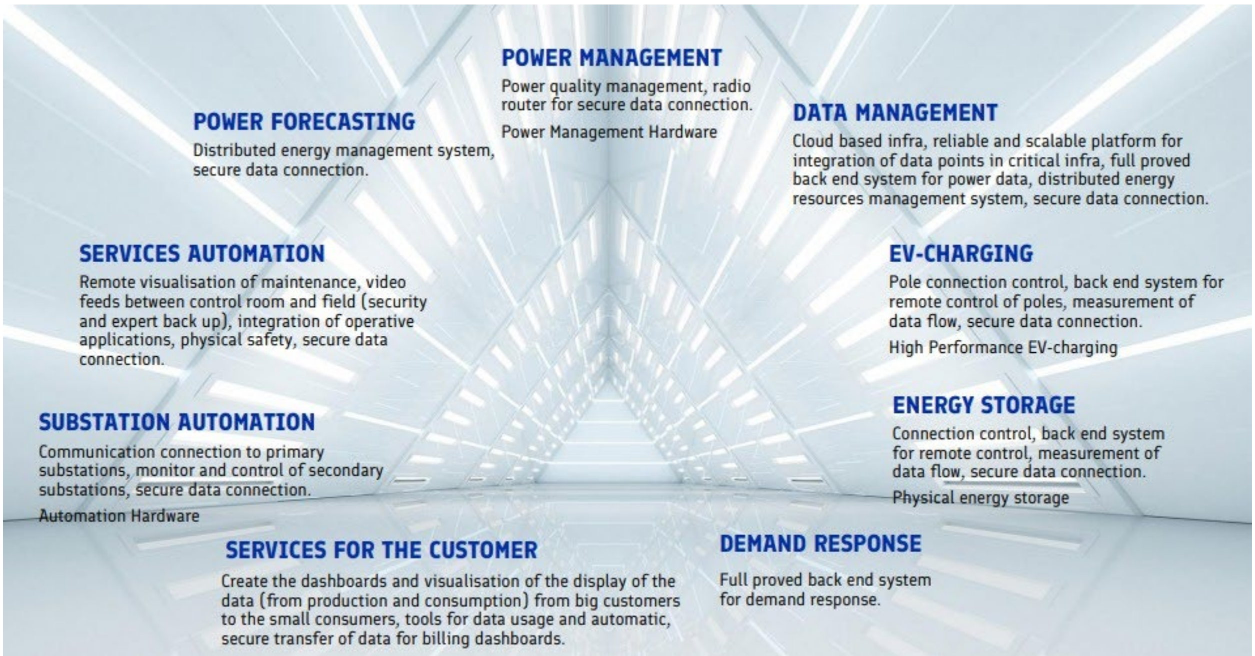

*Figure 7: Smart Energy hubs in Finland (Source: (*Business Finland - Smart Energy Finland*, n.d.))*

Figure 8: Smart Buildings Solutions in Finland (Source: (Business Finland, 2018)*)*

From these objectives, uses such as "Smart heating", "Smart Lighting", "Power Forecasting", "Demand Response" are identified, among others that seek to maintain the high stability of the Finnish electrical system in the face of the entry of renewable energies. Linked to the above uses also appears the idea of smart building solutions shown in Figure 8, this seeks to increase distributed generation, the automation of processes in buildings, among other improvements to achieve greater energy efficiency.

2.4.3 Japan

In Japan, the digitization of the energy sector is linked to the concept of society 5.0 that they are developing. Figure 9 illustrates the main aspects of Society 5.0, whose definition according to (*Society 5.0*, n.d.) is "A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space". For this reason, the focus on digitization is broader and there is a great importance in uses such as industrial robots, artificial intelligence in industry and autonomous vehicles.

This digitization plan has the support of companies such as TEPCO, which seek to introduce in Japan concepts such as mobile batteries (through electric vehicles) or the "Green Power Platform" which seeks to contribute to the entry of renewable energy through forecasting and "know-how" (Tokyo Electric Power Company, 2019).

In addition to the aforementioned, the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry is working on digitization at the distribution network level, highlighting concepts such as "Smart Communities", "Virtual Power Plants", "Demand Response", among others.(Ministry of Economy et al., 2018)

Figure 9: Society 5.0 in Japan (Source: (Society 5.0, n.d.))

2.4.4 China

The digitization of the industry is associated with the “Digital Transformation Partnership Action Plan 2020” (National Development and Reform Commission, n.d.), which is promoted directly by the National Development and Reform Commission, in conjunction with multiple government ministries, provincial and municipal governments, and regulatory agencies. It also includes a large number of private companies among which are: Alibaba, Xiaomi, Didi Chuxing, China Telecom, China Power and Lenovo. This program seeks to accelerate digital transformation in various industries and sectors, including small and medium-sized enterprises (SEMs). Accenture, for its part, has developed an action plan to Chinese enterprises, to propose a three-step digital transformation roadmap: ambition, action and achievement, the proposal of which is shown in Figure 10.

In energy matters, digitization has been framed within the 13th five-year plan, specifically in the “Energy Technology Revolution and Innovation Action Plan (2016-2030)” (The Energy Bureau of the NDRC (China), 2016), proposed by the National Development and Reform Commission (NDRC) and the National Energy Board. This plan determines the strategic direction in technological innovation and the route of key actions for the development of the necessary technology for the energy of the future. The objectives are to provide technical support for energy security, through clean energy, and to provide support for smart energy and low-carbon energy technologies. Among the concepts considered in this plan are the application of big data and IoT in the operation and maintenance of generation plants, use of 3D printing in gas turbines, energy trading platforms using cloud services, among others.

2.4.5 USA

In the US, the digitization of the energy sector is being carried out by the energy department and the transportation department.

The Department of Transportation is working on the implementation of autonomous vehicles, and there are currently 38 states that collaborate in the development and integration of these new technologies. In addition, the "Smart City Challenge" is being developed in this department, where one of its main objectives is to achieve an energy efficient transport system.

On the other hand, the energy department is focused on the use of new technologies in its electrical system, standing out for being the only country on the list to consider quantum computing and the quantum internet, mainly oriented to particle physics. In addition, Figure 11 shows the logo of the "Artificial Intelligence & Technology Office" where applications of artificial intelligence and machine learning are researched and developed for the energy sector (US Department of Energy, n.d.).

Figure 10: Digital transformation roadmap (Source: (Accenture, 2020).*)*

Figure 11: Artificial Intelligence & Technology Office Logo from the Departament of Energy (Source: (US Department of Energy, n.d.)*)*

This department has also invested in the integration of the IoT in the energy sector (DOE Advanced Grid Research, 2018), also appearing other technologies linked to this concept, such as "Smart Lighting", "DER Forecasting", "Virtual Power Plant", "Micro PMU ", among others.

Great importance is also given to cybersecurity, in particular the blockchain through the "Federal Blockchain Community", which can be very useful for the Chilean case considering how complex an attack on the electricity grid would be.

2.4.6 UK

Multiple entities are working on the digitization of the energy sector in the UK, the main one being "National Grid", which in the document (National Grid, n.d.) sets out its digitization strategy. This strategy is based on three pillars: Gathering Data, Generating Insight, Taking Action.

This strategy seeks to achieve better coordination, improve the customer experience, save costs, among other objectives. To achieve this, it is proposed to work with 4 focuses (detailed in (National Grid, n.d.)): Back Office, Grid Management, Customer & Stakeholder, New Products and Services. From this, uses such as "Network Forecasting", "Digital Twins", "Natural Language Processing", "Machine Learning" appear.

On the other hand, from the private sector, the digitization of the energy sector is also under development, by Moixa[3] and Gridbeyond[4]. These companies provide the demand side response service, adding uses such as "Virtual Power Plant", "Vehicle-to-Grid", and "Vehicle-to-Home".

In addition to private companies and National Grid, other government entities are working on digitization, one of them is "Innovate UK" where uses such as IoT, autonomous vehicles and smart city are added. Other relevant divisions are the Department of Energy and Climate Change and the Department for Business, Energy & Industrial Strategy and the Electric System Operator (ESO), where pillars for digitization are established and the issues to be addressed in each of them, as shown in Figure 12.

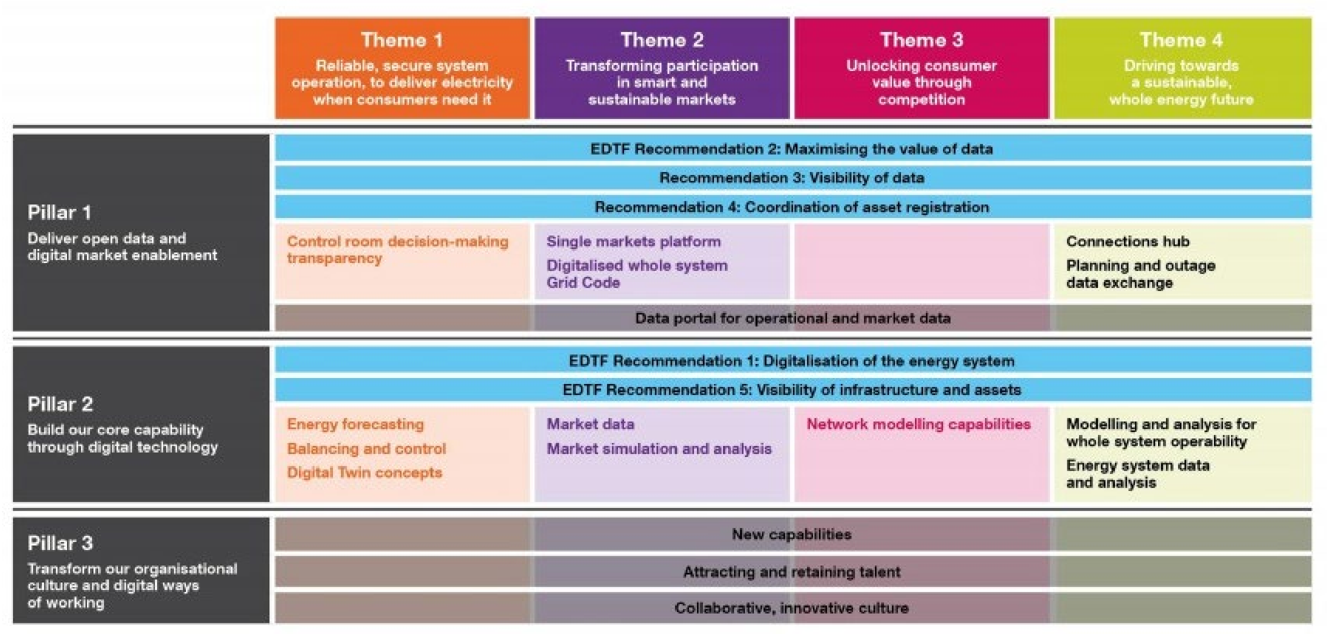

Figure 12: ESO digitalization landscape in UK (Source: (National Grid ESO, 2019)*)*

2.4.7 *Sweden*

The digitization of the Swedish energy sector is part of the objectives on which Smart City Sweden works, although there is no specific area devoted to this issue, its subareas contain uses and technologies related to the subject of interest.

The main focuses of this state platform are according to (Smart City Sweden, n.d.): "Climate, Energy & Environment", "Mobility", "Digitalisation", "Urban Planning" and "Social Sustainability". In these areas there appear uses and technologies such as "Smart

[3] https://www.moixa.com/business-services/
[4] https://gridbeyond.com/about-us/

Metering", "Demand-Side Flexibility", "BEMS", "Smart Buildings" and "Autonomous Vehicle", the latter being one of the most prominent use compared to other countries on the list as it has self-driving vehicles operating as part of research projects, or the implementation of an electric road in which vehicles are fed while driving. An example of the advances in autonomous vehicles is the case of the city of Östergötland, where as part of the "Ride the Future" program there are two autonomous electric buses operating at Linköpings University as shown in Figure 13.

On the other hand, Swedish Smart Grid also works on the digitization of the energy sector, focusing on distributed generation and technologies that facilitate its implementation and management, such as Artificial Intelligence and Smart Homes.

Other uses such as Smart Heating and Smart Lighting are considered by government institutions such as the Ministry of Enterprise Energy and Communication and the Swedish Energy Agency

Figure 13: Use of autonomous vehicle in Sweden (Source: Smart City Sweden, "Mobility Solutions for a Smart City")

2.4.8 France

In France, the Ministry of economy, finance and recovery (French: Ministère de l'Économie, des Finances et de la Relance), launched in 2018 the "France Num" initiative led by the General Directorate of Companies (*Lancement de France Num : Un Outil Au Service de La Transformation Numérique Des Entreprises | Economie.Gouv.Fr*, n.d.), whose objective is to support VSEs/SMEs towards digital, so that all enterprises can transform digitally in 3 years. The program includes a platform of personalized resources, technical advice, financing offers, and tailored tools and services. This initiative is in line with the vision put forward by the same ministry regarding the industry of the future in France, the pillars of which are shown in Figure 14.

For its part, EDF proposes to innovate in energy efficiency through digital solutions (*Digital Energy Efficiency Solutions | EDF France*, n.d.), in order to promote a better use of energy. This is why it is committed to providing its customers with digital solutions, such as "Smart meters"

An overview of the status and progress of French digital government is presented in the Digital Government Factsheet 2019 - France by ISA^2 (ISA2, n.d.). This document mentions the launch of "Techgouv" by the French government, whose program sets the path to accelerate the digital transformation of public services. Within the framework of the National Artificial Intelligence Strategy, comments are made about the second call for expressions of interest for experimentation with artificial intelligence in public services, the result of which is the development of 6 projects, among which a project to improve environmental police controls.

2.4.9 South Korea

The "Korea New Deal" (Ministry of Economy and Finance, n.d.), promoted by the Ministry of Economy and Finance of South Korea, is a strategic program for digital transformation at the national level after the COVID-19 crisis, with three fundamental pillars: Digital New Deal, Green New Deal, and Stronger safety nets. The entire program comprises a government investment of $133.1 billion. The program considers 10 major projects, among which are: Data dam, AI government, Green energy, Eco-friendly mobility of the future, among others. Among the enabling technologies included in this program are the use and application of big data and artificial intelligence, 5G integration and cloud computing. With this plan, it is expected to attribute intelligence to the city and the industry, also to promote the use and development of low-carbon green energy, and digital inclusion in rural areas of the country.

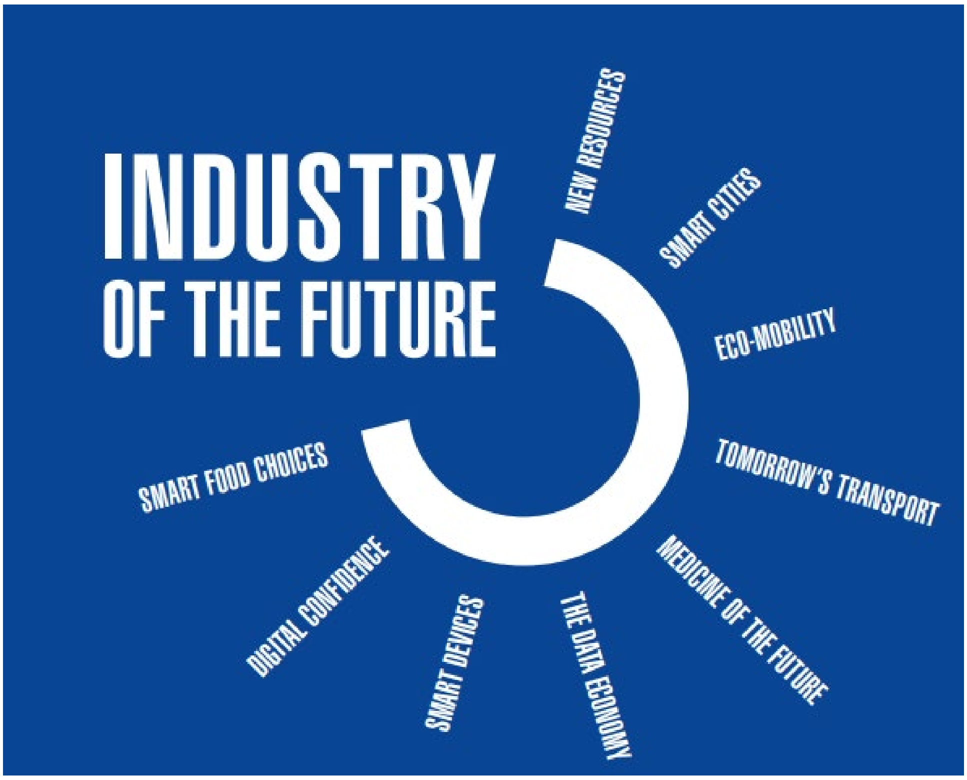

Figure 14: Industry of the Future in France (Source: Ministère de l'Économie, des Finances et de la Relance, "Rallying the «New Face of Industry in France»")

In addition, South Korea has implemented the Innovation Growth Engine (Ministry of Science and ICT, n.d.), whose initiative aims to strategically nurture new R&D-based industries, through Innovation and Growth policies, in order to prepare for the Fourth Industrial Revolution by 2022. The Growth Engine Planning Division of the Science, Technology and Innovation Office of the Ministry of Science and ICT, will lead the implementation of this plan, with the support of the Ministry of Trade, Industry and Energy, Ministry of Land, Infrastructure and Transport and Ministry of Health and Welfare, through its different divisions. This plan considers the following classifications for its different policies: The Intelligent Infrastructure, The Smart Moving Objects, The Convergence Service and The Industrial Base; which include concepts such as Big Data, Artificial Intelligence, Autonomous Vehicles, Smart City, Virtual and Augmented Reality, among others. The classifications mentioned with their respective technologies and considered are shown in Figure 15.

2.4.10 *Singapore*

In the case of Singapore, the nation's digitization efforts have been unified through Singapore Digital (SG: D), from the Infocomm Media Development Authority (IMDA) (*SG Digital - Digitalising Singapore - Infocomm Media Development Authority*, n.d.). Through the SG Digital Office ("SDO"), different government policies and initiatives are promoted to accelerate digital adoption for society and industry, providing tools and skills to each agent to participate in a meaningful way in the new social and economic environment post-COVID-19. This move includes a plan to develop a next-generation digital industry.

On the other hand, the "Smart Nation" initiative aims to ensure that all segments of society can take advantage of digital technologies and benefit from them, it seeks that people are enabled to use technology and that companies take advantage of opportunities to the digital economy (*Smart Nation Singapore*, n.d.). Part of these benefits for citizens are shown in Figure 16. The key domains covered by this initiative are health, transport, urban solutions, finance, and education. Plans are being promoted for the construction of a Digital Economy, Digital Government and Digital Society. Among the concepts that stand out in this movement are "Smart Metering", "Smart Lighting", "Smart City", "Smart Home" and "Autonomous Vehicle".

Figure 15: The Innovation Growth Engine (Source: Ministry of Science and ICT of South Korea)

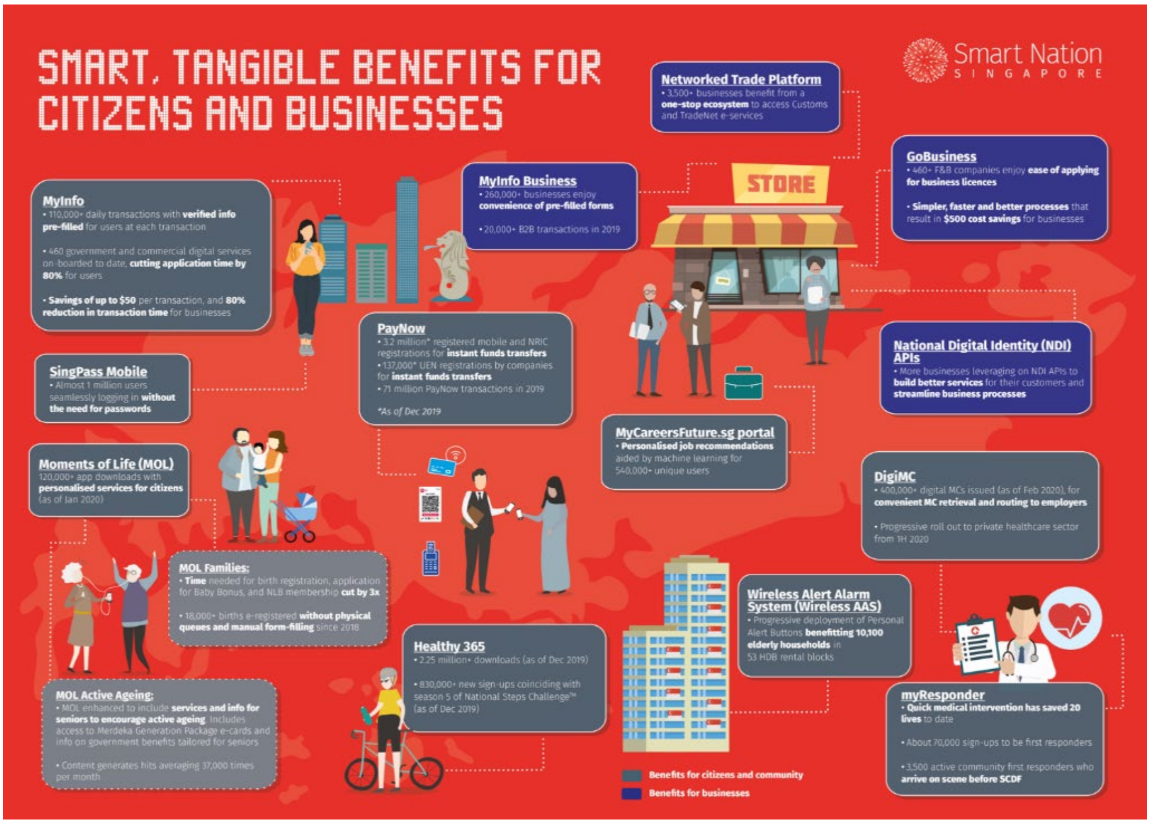

Figure 16: Smart, tangible benefits for citizens and business (Source: Smart Nation Singapore, "Transforming Singapore".)

2.4.11 *Countries that have led the development of applications and uses*

Based on the review of the ten countries, their public policies and outstanding examples of digitalization applications, Table 6 presents a summary of the list of applications and uses associated with those countries that have pioneered their development. Note this table does not show the countries where the application is being currently used, but rather a recognition of the countries that have led the applications' development.

Table 6: Digitalization application and uses associated with countries that have led their development.

Uses/Applications	Germany	Finland	Japan	China	USA	UK	Sweden	France	South Korea	Singapore
Smart substation		X								
Feeder automation					X	X	X	X	X	X
Microgrids	X		X	X	X	X	X			X
DSM/DR	X	X	X	X	X	X				X
Energy storage	X	X	X	X	X	X		X	X	X
VPP	X		X		X	X				X
Distributed energy (electricity/DG & gas)	X		X	X			X		X	X
Prosumer & P2P trades	X									
Retailing, billing & customer orientation	X	X								
Process optimization & automation (gas, oil & coal)					X	X				

Uses/Applications	Germany	Finland	Japan	China	USA	UK	Sweden	France	South Korea	Singapore
Emission monitoring			X		X	X			X	
Transportation for personal use	X	X	X	X	X	X	X	X	X	X
Public transport	X	X	X	X	X	X	X	X	X	X
Transport cargo	X	X	X	X	X	X	X	X	X	X
Shared mobility				X			X			
Predictive maintenance	X									X
Forecasting and predictive analytics	X	X			X	X				
Smart lighting		X		X	X		X			X
Smart traffic		X	X	X	X	X			X	
Smart home & building	X		X	X		X	X	X	X	X
Smart industry			X	X	X			X	X	
Smart farm				X		X			X	
Smart parking		X			X					
Smart waste management										
Smart fleet management		X				X				X
Market management & operation	X				X					
Ancillary services				X	X	X				
Energy management	X		X			X	X	X		
Operation (monitoring/control/reporting)					X	X				
Teleworking	X	X	X	X	X	X	X	X	X	X

3 Successful international business models / applications in different sectors

Following the international review of the state-of-the-art, in this section we identify different business models that have been developed to obtain the benefits of digitization. The analysis is based on the approach of (Osterwalder & Pigneur, 2010) which states that "the business model describes the basis on which a company creates, provides and captures value". This business model methodology allows us to understand how a company works, through the representation of the way in which companies are structured and operate. The business model represents a scheme that senior management uses to deliver products/services to customers, in a way that allows the generation of income that covers costs and leaves profits for the owners of the company. The business model links the company's strategy with economic logic to make the company profitable. In addition, it describes two primary elements: the value proposition for the consumer and the company's profit formula (see Figure 17).

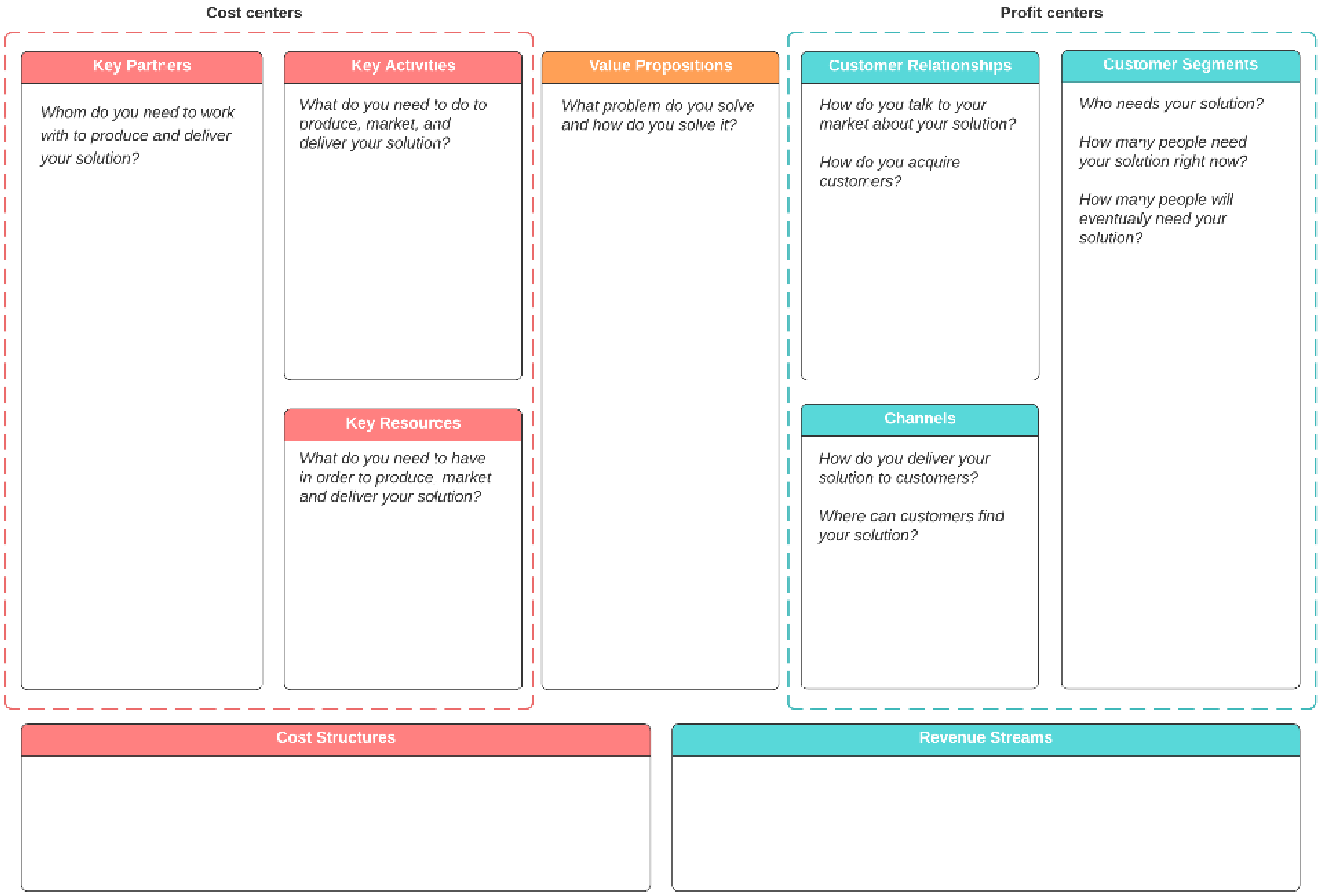

Figure 17: Business Model Canvas: nine business model building blocks (Source:(Osterwalder & Pigneur, 2010))

The international review is presented according to the above scheme, which highlights, in relation to the focus of this study, Value proposition, Costs Structures, Key Activities, Revenue Streams and Customer Segments. Table 7 shows some examples of business models for different uses and digital application which can affect the energy sector. Most of the examples presented correspond to the most relevant ones found at the international level. However, we have only been able to describe those cases where information was available. As it is sensitive information for companies, in general it was not possible to gather much information about it.

One of the most interesting initiatives involving several of the uses and applications relevant to the study corresponds to the Energy-as-a-Service model. Energy-as-a-Service (EaaS) is a delivery model that combines hardware, software and services (Deloitte, 2019). Solutions should combine demand management and energy efficiency services, facilitate the adoption of renewables and other decentralized supply sources, and also optimize the balance between demand and supply. The chief benefit for the consumer is in the simplification of an increasingly multifaceted service offering. Some examples of X-as-a-Service contract types are Lighting as a Service (LaaS) and Mobility-as-a-Service (MaaS).

Table 7: Description of example of business models

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
DSM	Moixa (UK)	Moixa provides a cloud-based software (GridShare) that connects distributed storage devices, electric vehicles charges (V2G technology), and distributed generation to the grid, acting like a Virtual Power Plant (VPP). This company provide the Moixa Smart Battery and Solar system. Owners of this battery can join to GrideShare membership and to be part of the VPP. Using this technology, the clients can optimize their consumption pattern and participate of the Demand Side Response (DSR) service of UK Wholesale Market.	Clients can reduce energy cost optimizing their demand consumption profile, taking account the price of the energy, renewable energy generation and the state of charge of batteries. Big and small clients, like residential clients, can participate of the DSR services, contributing to the frequency control to the system. DSR contributes to increase the participation of variable renewable energy source.	Development of energy management Software. Production of battery, solar panel, and addition hardware to provide DSR service. Participate of UK Wholesale Market.	Mainly residential and commercial clients, but also industries.	Development and maintenance of cloud-base software. Cost of Moixa Smart Battery and Solar system. The cost of this system then is paid by clients. Cost associated to participate of Whosele market.	Revenue due to the sale of Moixa Smart Battery and Solar system. Clients can participate of DSR through Moixa. It receives the revenues to participate of this service and part of these benefits are transferred to their clients.
DSM	Gridbeyond (UK)	Gridbeyond offers the Demand Side Response (DSR) service to industries and commercial clients. It identifies which client assets are suitable for DSR, and	Clients can reduce energy cost, and can participate of Demand Side Response	Production of energy management Software.	Industries and commercial clients.	Development and maintenance of cloud-base software.	Gridbeyond receive revenues to participate of Capacity Market and

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
		install the necessary equipment and technology to enable clients to participate of DSR services. The costumer data is collected in a cloud-based platform (CentrPoint) with use machine-learning algorithms to identify flexibility opportunities. There are several different markets within DSR, but the two most significant are the capacity market and firm frequency response (FFR).	services of UK Wholesale Market. DSR contributes to increase the participation of variable renewable energy source.	Identify potential client suitable for DSR, and install the necessary equipment and technology. Participate of UK Wholesale Market.		Equipment and technology to enable clients to participate of DSR services Cost associated to participate of Whosale market.	firm frequency response (FFR). Part of these benefits are transferred to their clients.
DSM, Smart Home.	OhmConnect (USA, CAISO)	By giving the company access to their smart meter data, customers can participate in events called "Ohmhours". Depending on their preference, clients get notification via SMS or email up to 4 times a week with their forecasted consume for the "Ohmhours". Clients earn "points" by consuming less than their forecast, and loss points by exceeding it. These points can be cashed out once per month. OhmConnect also offers automated solutions to participate in more frequent and shorter events called "AutoOhms" which can integrate with smart appliances. Clients can participate with	Clients can reduce energy cost, can participate of Balance Energy Services. DSR at the "Ohmhours" contributes to increase the participation of variable renewable energy source.	Accessing to private smart meter's data. Forecasting of individual consumption Correct setting of ratios between energy, points and money Software development. Integration with 3rd parties' smart appliances. Participation in Wholesale markets.	Domestic clients	Development and maintenance of cloud-base software. ADR enabled devices to lean in "SmartOhm" programs. Cost associated to participate of wholesale market.	Revenues from participating in wholesale market with Demand Response services. Part of these benefits are transferred to their clients. Revenues from "SmartOhm" subscriptions.

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
		their own smart equipment or join the "SmartOhm" program to use company-owned smart plugs, and also get other membership benefits					
Virtual power plant, Market management & operation	StromDAO (Germany)	Blockchain is used to create a "virtual power plant" with which participants can supply themselves by investing in off-site renewable energy and reselling part of the production on the spot market.	With the implementation of two blockchains customers can trace the origin of their energy consumption, and reduce their CO2 footprint.	Forecasting of renewable generation one day ahead. Software development Participation in Wholesale markets.	StromDAO energy suppliers (regional PV systems), private and business customers.	Development and maintenance of cloud-base software. Cost associated to participate of wholesale market.	Revenue comes from the energy management (Dispatch) for producers and households.
Market management & operation, Microgrids, Prosumer & P2P trades, DER management (use class), Distributed Energy, Retailing, billing &	LO3 Energy (USA)	LO3 Energy work with utilities and retailers to deliver a local energy marketplace that meets the demands of modern energy customers. Their technology platform, "Pando", offers a simple way to pool local distributed energy resources and enable customers to buy and sell local energy and optimize the grid at a community level. This platform is implemented using blockchain to ensure privacy and security	Local agents can trade energy products in a local market with custom rules. Utility or retail company gets insights on their client's preferences and engagement within the community.	Accessing to private AMI's data. Software development.	Utility or Retail company implementing the marketplace. Small generators, consumers and prosumers trading in the platform.	Development and maintenance of cloud-base software.	Utility or retail company pay for software related services.

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
consumer orientation							
DER management (use class), Energy storage, Energy management, Smart home & building, Predictive maintenance, Smart industry	Schneider Electric (France)	EcoStruxure is Schneider Electric's IoT-enabled, plug-and-play, open, interoperable architecture and platform, in Homes, Buildings, Data Centers, Infrastructure and Industries. Innovation at Every Level from Connected Products to Edge Control, and Apps, Analytics and Services.	EcoStruxure's digital solutions enable sites to achieve lower energy use, greater occupant comfort, higher productivity and simplified operation through a combination of energy management, automation, and IoT connectivity. It is this same IoT connectivity that enables app-based environmental control over lighting and temperature, in buildings; or connects inventory to smart sensors across the supply chain, in industries.	Software development. Robust hardware support Strategic digital alliances (Microsoft, Accenture, Intel, Cisco)	Public Sector, commercial and residential buildings. Industrial plants. Data centers.	Development and maintenance of cloud-base software.	Revenues come from software related services, technical support and consultancy,
Distributed energy, Emission monitoring	I-REC (Europe), Green-e (USA)	A renewable energy certificate, or REC, is a market-based instrument that represents the property rights to the environmental, social and other non-power attributes of renewable electricity generation. RECs are issued when one	Certification of renewable energy generation is useful for companies that want to declare the use of clean energy in their production.	Issuance of certificates in each country (issuers are responsible for reporting on each certificate, the	Renewable electricity generation companies and companies that	Costs of certification, intermediaries and verification standard.	Income from the purchase of certificates and subscription to the service. Additional price margin by

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
		megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource[5].		generation technology, among other data). Generation of electricity (owner of the certificates). Sale of certificates through intermediaries (or trader) or directly to the final consumer.	require clean energy.		valuation of the renewable attribute.
Distributed energy, Emission monitoring	Certificados de Energías Limpias, CEL (México)	A CEL is a certificate or bond, priced at market value, that an electricity generator can place in a specific market. A CEL is equivalent to 1 megawatt-hour (MWh) of electricity, generated with renewable energies such as wind, solar, hydraulic, among others.	It corresponds to financial instruments through which the use of clean energies is promoted, the energy matrix is diversified, competition between clean and conventional energies is promoted and, in most	The validation is controlled by the Energy Regulatory Commission (CRE).	Green / renewable generators whose generation is 100% clean energy. Combined cycle generators or co-generators (1	Costs of certification, intermediaries and verification standard.	Income from the purchase of certificates.

[5] https://www.epa.gov/greenpower/renewable-energy-certificates-recs

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
			cases, the cost of energy is reduced.		CEL for every 5 MWh generated)		
Smart lighting	Deloitte (UK)	This business model has become more common in commercial and city-wide installations of LED lights, specifically in retrofitting buildings and outdoor facilities, with the aim of reducing installation costs. Lighting vendors have used a LaaS strategy to sell value-added services, such as Internet-connected lighting and energy management (Lighting as a service).	Value is generated by bundling into a single offering the various elements that are usually sold separately. Lighting as a Service (LaaS) is a service delivery model in which a lighting service is charged on a subscription basis rather than via a one-time payment.	Development of on- and off-site energy supply solutions, including PPAs, and energy storage and management. Strategic guidance across procurement, financing, operations and maintenance of the customer's entire energy portfolio.	Utilities; industrial companies; tech companies; specialist renewable providers; telcos and start-ups.	Costs, including equipment, construction, operations, monitoring and maintenance, are the responsibility of the service provider.	The customer pays for an all-inclusive package, and not per unit consumed.
Transport for personal use, Transport cargo	Innogy, MakerDAO, Share & Charge Foundation (Germany)	E-mobility wallet is an electronic wallet mechanism through blockchain with which invoices for energy charging of electric vehicles can be managed.	Customers can charge their EVs using a large network of stations and pay using DAI, a stable crypto currency. Thus, providing a decentralized, private and transparent payment option.	Software development Association of charge stations owners (Innogy), charging network (Share & charge Foundation) and crypto-currency party (MakerDAO)	Private EV owners	Development and maintenance of cloud-base software.	No direct revenue streams

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
Smart Home & Building	Honeywell International, Inc.	It is an American multinational conglomerate company that produces a variety of commercial and consumer products, engineering services and aerospace systems for a wide variety of customers, from private consumers to major corporations and governments. The company operates three business units, Honeywell Aerospace, Honeywell Automation and Control Solutions, and Honeywell Performance Materials and Technologies.	Honeywell provides value to its clients in the following ways: its industry experience and expertise; its brand recognition and reputation; its security and reliability; and the quality of its products and manufacturing process, with the Company providing a range of high-quality products.	Honeywell is a technology and manufacturing company. Regarding the Automation and Control Solutions (ACS) segment, offers a range of environmental, energy solutions, productivity, security, and industrial safety solutions.	Homes, commercial buildings and industrial facilities.	Honeywell incurs costs in relation to the operation of its research and development facilities, the management of its supply chain, the production and storage of its products, the sale and distribution of its products, the management of its partnerships, and the retention of its personnel.	Revenues at Automation and Control Solutions Sales include revenues derived from the sale of energy, safety and security products, and the sale of building solutions and distribution services.
Mobility (use class), Smart traffic	Chargepoint (USA)	Chargepoint sells charging stations for electric vehicles. These stations have smart features related to software and network, and are designed to be distributed at large scale, and shared among private owners. Chargepoint also sells software services to operate the network of distributed charge stations, with which station	ChargePoint creates value for owners by installing EV charging stations to help companies attract customers, tenants, or employees, increase property value and duration of tenancy, and establish brand around green leadership.	Software development Charging station R&D Strategic association with third party charging networks to provide roaming	Industrial, commercial, public sector and domestic buildings. Electric vehicle fleet managers EV owners	Development and maintenance of cloud-base software. Manufacturing and selling of charging stations.	Revenues come from charging stations selling, software services, and hardware/software support.

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
		owners can manage who use their stations and at what price.	ChargePoint creates additional value with the software and network, helping owners manage energy use, encourage efficient use of charging stations, control pricing, and understand energy patterns and greenhouse gas reductions.	services to Chargepoint users.			
Shared mobility	MaaS Global (Finland)	Mass Global developed the Whim app which offers in the same application different transport mode options. Allows users to subscribe and access a complete package of transport systems: public transport, city bikes, taxis, rental car, and E-scooter (Mobility as a Service).	User can buy ticket without subscription fee, but also can access to monthly plans. It also offers to consumers an alternative to car ownership.	Development of mobile application. To contact to transport service providers (car sharing, taxis, bikes, etc) to offer the service.	People (Residential sector)	Development and maintenance of app.	Fee due to travel ticket or plans income by using the Whim app.

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
Smart Industry	Xometry[6] (US)	This company offers the Metal 3D Printing service using a manufacturing infrastructure, where equipment, and other manufacturing capacity, is networked to enable more efficient production. Currently, this company offers access the production capacity of over 4,000 manufacturers. Customer can send an order for a part, and based on workload, materials, workforce availability, location and scale, the network will dynamically route the order to a given facility, or set of facilities, to most efficiently fulfil the request.	Make available the installed capacity of different 3D printing factories, which can be accessed by different clients. Customers can access this service through an online queuing system.	Development of cloud base service. To join manufacturing capacities of 3D technology.	Industries from aerospace & defense, automotive, education, electronics, energy, medical & dental medical, robotics, and other sectors.	Development and maintenance of cloud-base software. Investment, maintenance and operation cost of 3D printers and/or cost associated to manufacturing which provide this service.	Income related to 3D Printing and other associated services.

[6] https://www.xometry.com/

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
Smart Industry	General Electric, COBOD[7], and LafargeHolcim (United Stated)[8]	They use 3D printed concrete bases. Printing the base directly on-site with 3D-printed concrete technology will enable the creation of larger bases and cost-effective taller hybrid towers, reaching up to 200 meters.	Tall tower bases become too large to be transported over the road. Taller wind turbine will increase renewable energy production while lowering the LCOE.	Development of 3D printed concrete bases. Identify potential wind developers' clients.	Power generation	Investment, maintenance and operation cost of 3D printers and/or cost associated to manufacturing which provide this service.	Income related to 3D Printing and other associated services.
Smart Home & Building	Wiser - Schneider Electric and AutoGrid's Energy Data Platform (EDP), France[9].	Wiser is a complete connected home solution that can control various home functions, either remotely with the Wiser by SE app, and locally with connected switches, or with voice control via Amazon Alexa, Google Assistant, and Tmall Genie. It supports the following home functions: temperature control, lighting control, curtain and shutter control and entertainment control. Wiser is integrated with AutoGrid's Energy Data	Wiser brings to the end user comfort, convenience and safety at home, with a good design and high-quality products. Wiser Powered by AutoGrid will allow utilities to reduce peak power, curb emissions, and improve energy productivity to effectively	Identification of household requirements. Provision and installation of the devices. Analysis of multiple streams of data originating from smart meters, grid sensors, and other	Residential market for either individual or collective buildings. It can be implemented in new build or renovations. Utilities of all sizes, grid operators,	Investment in the purchase and installation of the devices. Maintenance of the system.	Energy savings from the use of the system (Wiser) and lower costs and improve reliability of the electricity supply chain

[7] https://cobod.com/
[8] https://www.ge.com/news/press-releases/ge-renewable-energy-cobod-and-lafargeholcim-co-develop-3D-printed-concrete-bases-wind-turbines
[9] This model is similar to the offered by Schneider Electric™ and AVEVA™.

Use / Application	Institution / Companies	General description	Value proposition	Key Activities	Customer Segments	Costs Structures	Revenue Streams
		Platform (EDP), a cloud-based Big Data platform for managing and optimizing the electricity grid connecting utilities and consumers, enabling homeowners to better control energy consumption.	utilize more of the electricity that is generated on the grid by enabling users to have a closer connection to their energy information.	energy management systems. Modeling of the transmission and distribution networks, weather feeds and customer demographics to generate forecasts concerning power consumption and grid conditions. The forecasts serve as the basis for strategies to dynamically reduce peak consumption and effectively manage power quality in the presence of intermittent renewable resources such as solar and wind.	electricity retailers and ESCO services companies.		

4 State of local Developments

4.1 Map of local actors

Considering the past experiences of the Energy Center, the following map of local actors shown in Table 8 is provided.

Table 8: Map of actors

Institution type	Examples	Sector	Potential use and application(s) under consideration
Distribution system operators	Enel Distribución, Saesa, CGE, Cooperativas eléctricas.	Energy	Smart grids: smart substation, feeder automation, microgrids. DER management: energy storage, distributed generation, demand aggregation. Customer domain: Prosumer & P2P trades, Retailing, billing & customer orientation. Data management: Predictive maintenance, Forecasting and predictive analytics.
		Building	Smart City: smart home & building, smart lighting. DER management: demand side management, distributed generation. Mobility: all
Energy providers and other energy services (Dx level)	Asociación Chilena de Comercializadores de Energía, Transelec.	Energy	Smart grids: microgrids. DER management: energy storage, demand aggregation, distributed energy.
		Building	Smart City: smart home & building, smart lighting. DER management: demand side management, distributed generation. Mobility: all
Energy generation	Colbún, Engie, Enel, Acciona, etc.	Energy	Smart grids: smart substation, microgrids. DER management: energy storage, distributed generation, VPP. Customer domain: Prosumer & P2P trades, Retailing, billing & customer orientation. Data management: Predictive maintenance, Forecasting and predictive analytics. Other: market management & operation, operation (monitoring/control/reporting)
Technology services providers	SONDA, IBM, Conecta, Oracle.	Industry	Process management: Process optimization & automation. Other: all
Blockchain-related services providers	Phineal, Kibernum	all	Other: market management & operation, operation (monitoring/control/reporting)
Energy service companies (ESCO)	Efizity, Vivendio	Energy	Smart grids: microgrids. DER management: energy storage, demand side management, distributed energy.
		Building	Smart City: smart home & building, smart lighting. DER management: demand side management, distributed generation.

Institution type	Examples	Sector	Potential use and application(s) under consideration
Construction and building companies and agencies	Camara Chilena de la Construcción, Justwe, Xenitt, etc.	Building	Smart city: smart home & building, smart lighting. DER management: demand side management, distributed generation. Other: energy management.
Transportation-related services companies	Uber, Cabify, Waze, CamionGo	Transport	Mobility: personal use, shared mobility. Data management: forecasting and predictive analytics. Smart city: smart fleet management, smart traffic.
Ride-sharing and ride-hailing services companies	AWTO, AllRide, Didi, EasyTaxi, Beat	Transport	Mobility: personal use, shared mobility. Data management: forecasting and predictive analytics. Smart city: smart fleet management, smart parking.
Liquid and gas fuel distribution and products companies	COPEC, Metrogas, Abastible	Transport	Mobility: all. Data management: predictive maintenance, forecasting and predictive analytics.
Telecommunications companies and ISP	Movistar, VTR, Entel	Industry	Smart city: smart industry. Other: market management & operation, operation (monitoring/control/reporting)
Public sector	Superintendencia de Electricidad y Combustible (SEC), Comisión Nacional de Energía (CNE), Coordinador Eléctrico Nacional (CEN), Ministerio de Energía, Ministerio de Transporte y Telecomunicaciones, Ministerio de Hacienda, Ministerio de Ciencia, Tecnología, Conocimiento e Innovación, Intendencias, Gobierno Digital (SEGPRES), Gobernaciones regionales, Municipalidades.	Public sector	Customer domain: all. Mobility: all. Data management: all. Smart city: all.
Finance sector	Bolsa de comercio, Bancos	Finance	Smart city: smart industry. Customer domain: prosumer & P2P trades. Data management: forecasting and predictive analytics. Other: market management & operation, operation (monitoring/control/reporting)
Research centers	Centro de Energía U.Chile, Centro de Innovación UC, Centro de Innovación Energética (CIE), Fraunhofer Chile, Centro de Desarrollo Energético Antofagasta (CDEA), Centro Smart City Lab (Usach), Smart Center (UAI), etc.	all	all
Mining companies and agencies	Consejo Minero, Corporación Alta Ley	Industry	Smart city: smart industry. Other: energy management, operation (monitoring/control/reporting)

4.2 Contribution of digital uses and applications in the NDC

In this section the research team analyzes how digital uses and applications could support or incentivize the development of the measures included in the updated NDC proposal and the carbon neutrality target by 2050. Figure 18 shows the abatement curve of the measures included in the NDC proposal.

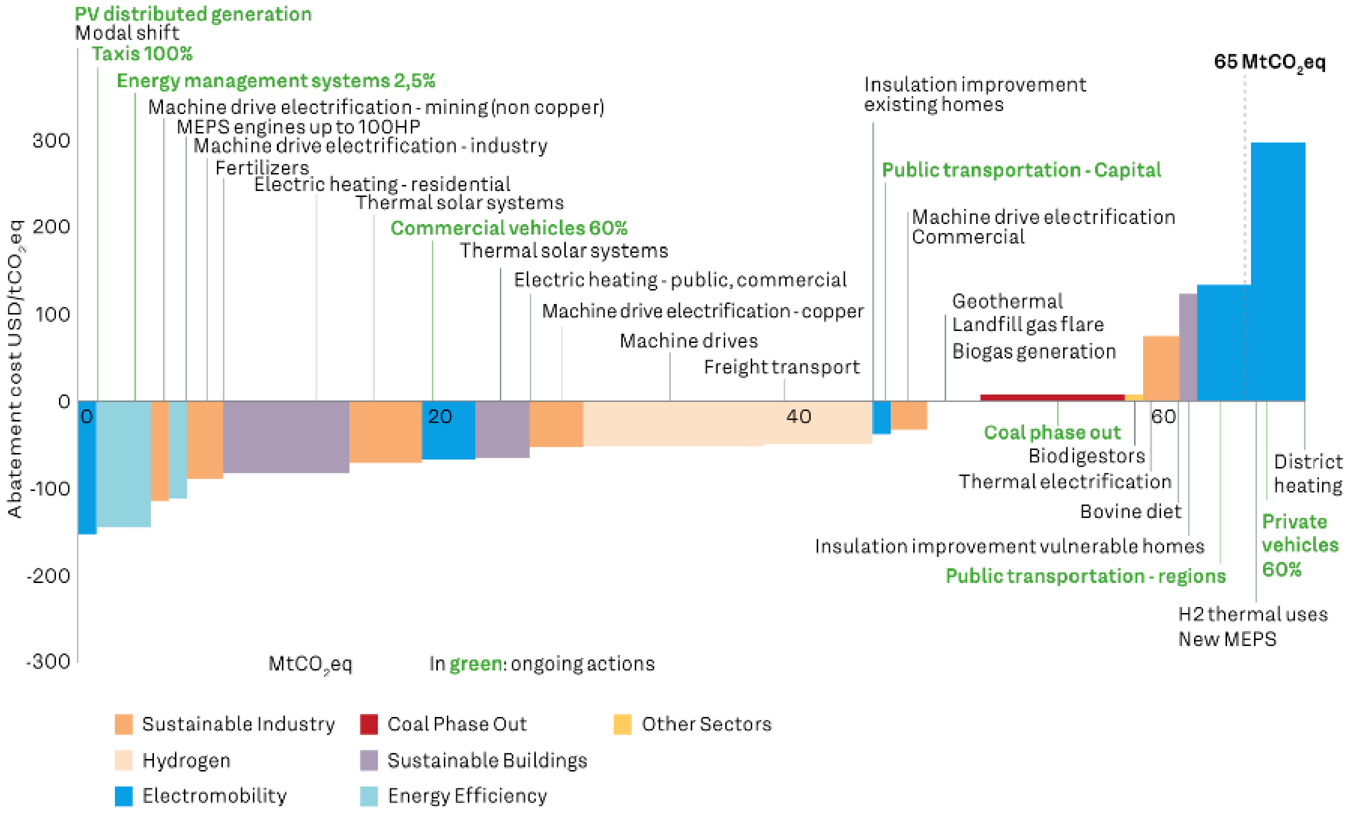

Figure 18: Abatement curve and mitigation action included in updated NDC.

Table 9 identifies how some applications could encourage the development of some of the measures included in the NDC. In general, most of the digital uses/application identified in this Chapter are not included explicitly in the NDC. For example, Demand Side Management, Storage, VPP are digital application can contribute to the integration to more variable renewable energy source, and therefore, to facilitate the decommission of coals plants (or accelerate) and integrate more renewable level at distributed level. In this case, probably these digital applications will not provide additional emissions reduction to the current projection in the NDC. Other uses and applications, not currently included in the NDC, also have been identified. For example, the teleworking (widely used in the Covid-19 health crisis of 2020) is not included in the NDC update, however, this measure could contribute to reducing emissions by reducing the amount of road and air transport. The use of information technologies to optimize the routes and logistics of transport companies, which could reduce time and energy consumption, is also not included in the NDC. Currently there are international experiences which make use of 3D printers to manufacture large-scale products in places near final use. The use of this technology allows the development of products in a cost-efficient manner, reducing manufacturing times, product transfer and import times, and disposing of products in places that without this technology would be difficult to obtain.

Table 9: Contribution of digital application to the national GHG emission reductions.

Use/Application	NDC Mitigation actions promoted by digitalization	Impact on emission reductions
Demand Side Management	PV distribution generation	Demand Side Management can participate of frequency control of the system. This can contribute to integrate more

Use/Application	**NDC Mitigation actions promoted by digitalization**	**Impact on emission reductions**
	Energy Management Systems Coal phase out Electromobility (station charger)	variable renewable energy sources (like a wind and PV) and reduce the operation cost of the electrical power system. According to (McKinsey & Company, 2010), the level of demand- side management will increase from 2 percent in 2020 to 10 percent in 2050.
Storage	PV distribution generation Energy Management Systems Coal phase out Electromobility (station charge)	Storage can reduce the variability generation of renewable energy source. In addition, storage system can participate of frequency control of the electrical power system. This can contribute to integrate more variable renewable energy and reduce the operation cost of the electrical power system.
VPP	PV distribution generation Energy Management Systems Coal phase out Electromobility (station charge)	Storage can reduce the variability generation of renewable energy source. In addition, storage system can participate of frequency control of the electrical power system.
Distributed energy (electricity / DG & gas)	PV distribution generation	Promote the development of PV distribution generation.
Prosumer & P2P trades	PV distribution generation Coal phase out Geothermal	Promote the development of renewable energy sources in order to certify the instantaneous energy consumption is provided by renewable energy sources ("green certificates"). Considering that the RECs will not change the penetration of on-grid renewable projects, it is assumed that the increase in penetration will be in off-grid projects. The average growth of the last 5 years has been 125%. Above this average, the increase in installed capacity should be between 5% and 10%, with a similar reduction in GHGs.
Shared mobility	Modal shift Public transportation Electromobility	Reduce the number of motorized trips, then the energy consumption. Use of less energy intensity vehicles or non-motorized vehicles
Teleworking	No included in NDC	This measure could contribute to reducing emissions by reducing the amount of road and air transport. According to a review of international studies teleworking could reduce carbon emissions by between 0.1% and 80%, with this higher estimate assuming a five-day teleworking routine by the whole population. But there could be an

Use/Application	NDC Mitigation actions promoted by digitalization	Impact on emission reductions
		increase in emissions if the policy is not properly implemented (Hook et al., 2020).
Smart lighting	Energy Management Systems	The use of smart sensors could promote the optimization and reduction of energy consumption associated with heating, lighting, etc. According to Philips Lighting there is a potential to reduce 15% of total electricity consumption and 5% of greenhouse gas emissions.
Smart fleet management	No included In NDC	The use of information technologies to optimize the routes and logistics of transport companies, which could reduce time and energy consumption, is also not included in the NDC.
Smart industry-3D printing	No included in NDC	The use of this technology allows the development of products in a cost-efficient manner, reducing manufacturing times, product transfer and import times, and disposing of products in places that without this technology would be difficult to obtain. In (L. A. Verhoef et al., 2018) it is estimated that additive manufacturing, as 3D manufacturing is known, could reduce energy consumption between 5% and 25%.

Chapter 2: Analysis of gaps and opportunities

5 Goals, gaps, barriers and opportunities

In this section, the definitions for the key concepts used in this document are presented. Each one of these concepts, although presented here in general, will have a special meaning for the international analysis and for the national analysis, as explained in the brief introduction of Sections 6 and 8.

5.1 Goals and gaps

Even though the term “gap” has several definitions (i.e. dictionary entries), for the purposes of this project, the concept will be associated to separation, or “distance”, between an initial state and a desired state. The term “breach” will be considered a synonym in this context, although breach is usually associated with violation of a condition (as in “security breach”). Nevertheless, in this report both terms will be used interchangeably.

For a gap to be well defined, the notions of initial state and desired state need to be clear. In this project, the initial state corresponds to that of the current situation (state of the art), while the desired state corresponds to that associated with desirable goals, such as levels of penetration or massification of a given application or enabling technology, a disparity that needs to be addressed (such as the digital gap or digital divide), among others.

Goals and gaps for the ten key countries are recognized, as well as for Chile, whenever those for the latter are reported.

5.2 Barrier

This concept, as adopted in this project, refers to the cost, obstacle or impediment that prevents the proliferation, access or use of an application or technology related to digitalization. This is inspired in the concept of “barriers to entry” usually found in economics literature.

5.3 Opportunity

This concept refers to favorable or positive circumstances that are generated in the environment and that, once identified, can be taken advantage of. The concept includes elements such as favorable market trends, economic situations, technological changes, among others.

6Gaps, barriers and opportunities detected in the international arena

In this section, the gaps, barriers and opportunities for each digitalization use/application classified in Chapter 1 are presented. For each use, the goals that countries have set for themselves (from the list of 10 key countries, to the extent that existing information permits), what gaps they are/were associated with, and the path they are following (e.g. public policy that encourages the development of an application or enabling technology) are analyzed. If the information is not available, qualitative goals will be defined (low - medium - high, for example). The barriers that digital uses and applications have had to face, as well as the barriers that are addressed from public policy will be also recognized. Finally, the main opportunities associated with digital uses and applications will be identified.

6.1 *Smart Grid*

The electricity system of the future faces the scenario of bidirectional flows, a high penetration of distributed resources and a greater participation of the demand. Smart grid-related solutions aim at an improvement in the control and monitoring of the different equipment and facilities of the network by the joint implementation of granular sensing equipment (such as PMU), ICT systems and control algorithms.

Improvement in the control and monitoring of the grid and its assets can lead to a faster response in emergency events, to a reduction of customers affected by outages, and reduction of recovery times when a service outage occurs, thus improving the resiliency and reliability of the network and giving a better supply to end users. Information on the state of the grid and power flows together with active management of grid resources could enable greater incorporation of distributed resources such as DG and EV. These technologies also present opportunities for more decentralized grid operation and better engagement of communities. In this section, the use of smart substations, smart feeders and microgrids. is analyzed.

6.1.1 *Smart Substation*

6.1.1.1 **Opportunities**

- Improved control and monitoring of substations enable the reduction of maintenance and operation costs, reduction of physical space, improve the safety of service personnel and collection of more accurate information[10].
- Better, faster communication technologies allow an adequate response to contingencies.

6.1.1.2 **Breaches and goals**

In the case of this use, the breaches analysis focused on the review of the experience in the UK and Finland.

10 https://search.abb.com/library/Download.aspx?DocumentID=4CAE000291&LanguageCode=es&DocumentPartId=&Action=Launch

- UK: The Smart Grid Enablers project of the British public utility Northern PowerGrid seeks to modernize all its 8,000 substations by 2023, to prepare the network for the sudden increase in DERs. This project aims to reduce the company's carbon footprint, achieve energy efficiency savings of up to £ 500 million by 2031 and become a distributed system operator. The program aims to develop a platform that allows Northern PowerGrid to monitor and control its substations in a coordinated manner and without interruptions, which entails the need for a cybersecurity system to face possible attacks; in addition, the review of the communications system.
- Finland: Among its strategies for flexibility and digitization of the energy sector, it is worth highlighting the incorporation of substation modernization in order to make them intelligent, through communication systems, hardware automation and incorporation of remote control and monitoring systems, all of the above accompanied by a complete data security system. The objective is to achieve the joint modernization of the grid to increase the use of renewable energy and abandon the use of fossil fuels.

6.1.1.3 Barriers

- The digitalization of substations requires reviewing the communications system so that it is prepared to respond quickly. For example, the use of fiber optics makes communication systems more expensive, but it contributes in transmission speed.
- Since the data is correlated to the infrastructure, it is considered that the sovereignty of the data should be in charge of the system operator. This must be explicitly defined in the respective regulation. There is an important need to protect data against security attacks, as a high risk exists if the system is breached.

6.1.2 *Feeder Automation*

6.1.2.1 Opportunities

Through the improvement in the control and monitoring of the distribution network, there is a greater possibility of recognizing the origin of a contingency, which could generate a faster response for its clearance and reduction of failure time.

Information on the state of the grid could be useful for the incorporation of distributed resource management, in order to generate changes in the DERs configuration according to the needs of the grid.

6.1.2.2 Breaches and goals

For the gap analysis, the cases of UK, USA and Japan are reviewed:

- UK: This use is linked to UK networks transition challenges, in order to reach the desired state, a regulatory framework must be established that encourages and allows this transformation in the grid, and an adaptation of the grid to support these new technologies (Energy Technologies Institute LLP, 2016).
- USA: In the United States the Smart Grid initiative that seeks to modernize the grid, the use of feeder automation can be associated to the gap on improved performance of the feeders and a greater integration of data analytics in the system (Torres, 2011).
- Japan: In the document "Opportunities and challenges for smart grids in Japan" developed by TEPCO (Ashidate, 2016) describes the desired state of smart grids, where this use participates as part of the coordination of the grid. From the document it can be deduced that the gap between the current state and the desired one is a greater use of technologies such as big data and cybersecurity, in addition to the greater participation of agents such as consumers or aggregators.

6.1.2.3 Barriers

Incorporating technologies in grids whose current level of digitization is low, becomes very expensive. In addition, the need to collect information requires infrastructure that customers may not want to accept.

6.1.3 *Microgrids*

6.1.3.1 **Opportunities**

This is a highly relevant application in buildings whose connection to a reliable grid is crucial. Taking it to the extreme, a complete grid composed of many microgrids is capable of isolating during contingencies, which translates into continuity of electricity supply to consumers. When a major contingency occurs in a grid and the microgrid is in connected mode, it is capable of isolating and work as a self-sufficient system.

The use of enabling technologies in this application would facilitate the incorporation of other digital applications. For example, microgrids foster end user participation, which can be reflected in the adoption of DSM/DR programs.

Also, there is a great opportunity to provide electricity to towns and settlements currently disconnected from the electricity grid for technical or economic reasons.

6.1.3.2 **Breaches and goals**

- USA: The Department of Energy's Smart Grid R&D Program considers microgrids as a key building block for a Smart Grid (Ton & Smith, 2012). The microgrid performance target for 2020 is "To develop commercial scale microgrid systems (capacity<10 MW) capable of reducing outage time of required loads by >98% at a cost comparable to non-integrated baseline solutions (uninterrupted power supply [UPS] plus diesel genset), while reducing emissions by >20% and improving system energy efficiencies by >20%, by 2020"..
- EU: Microgrids are expected to co-exist with the more centralized systems. Building these bridges across systems will allow for better security of supply (microgrids being able to support the central system and vice-versa) and more opportunities to value decentralized generation. The opportunities of integrating microgrids together and with the central power system will be facilitated in the future as digitalization progresses. By the end of 2017, there were 1.8GW of installed microgrid capacity in Europe. European projects are predominantly located in remote, sparsely populated areas. Between late 2012 and late 2017, microgrid capacity in Europe increased almost 6-fold. However, this is a slower rate than elsewhere in the world. The most recent report (2017) shows that there are 28 ongoing projects (with fully completed entries in the JRC database). There is not much information about specific goal tied directly to microgrids, but they are considered to be an important factor in the energy transition. So, it can be related to "The Clean Energy for all Europeans Package" and its objectives (ENTSO-E, 2019).
- Singapore: No specific goal declared for microgrids were found but, one of the sustainable goals of the country is "Ensure access to affordable, reliable, sustainable and modern energy for all" (UN SDG number 7) which can be associated with microgrids (Statistics Singapore, n.d.). This goal is broken down into five targets: 1) Universal access to modern energy, 2) Increase global percentage of renewable energy, 3) Double the improvement in energy efficiency, 4) Promote access to research, technology, and investments in clean energy, and 5) Expand and upgrade energy services for developing countries.

  Currently, in Asia, there are millions of people without proper access to modern energy services, and microgrids are a potential solution for those people. The Renewable Energy Integration Demonstrator – Singapore (REIDS) is the largest hybrid microgrid test and research platform in the tropics. Launched by the Nanyang Technological University Singapore, supported by the country's Economic Development Board and National Environment Agency, REIDS aims to study, and demonstrate the ability to achieve sustainable, affordable energy access to all parts of Southeast Asia (VanadiumCorp Resource Inc., 2017).

6.1.3.3 **Barriers**

Microgrids faces technical, regulatory, financial and stakeholders' barriers. From the technical point of view the barriers may be technological issues like dual mode of operation (on/off grid), or frequency control and safety. On the regulatory side, microgrids may be pushed back by interconnection rules or their Bi-directional power flow and ability to trade locally. Even if all the technical and regulatory barriers would be alleviated, the commercialization of the microgrid concept heavily depends on the reduction of production costs of renewable energy generation, storage technologies, and energy management systems.

Finally, the stakeholder's barriers are those related to the trust of constituents and managing the operation of the microgrid itself.

6.2 Distributed Energy Resources (DER) Management

This class focuses on uses whose objective is to manage the existing distributed resources in the grid, and to facilitate the entry of new distributed resources or modify existing ones in order to obtain a more dynamic grid at the distribution level, that allows cost reductions and improvements in the general operation of the system. Through the injection of energy directly at the consumption points, it is possible to supply said consumption and the surpluses to be injected into the grid, generating bidirectional flows which contribute to the decongestion of the grid and improvement in the voltage profiles.

Considering the focus that this class has, its opportunities are oriented towards increasing renewable resources and also increasing their relevance in the context of the climate crisis. Examples of this are the benefits to the uses of distributed energy, through residential solar, mini-hydro generation, or energy storage that takes relevance in systems with high penetration of NCRE to address the variability of these sources. On the other hand, the inclusion of new agents and greater participation of the distribution network also implies new goals and barriers for this participation, such as the increase in access to user information for the DSM / DR or VPP, or the regulation of the participation of these new agents in the market ("How do I control the maintenance of a VPP?").

Next, a detailed review is carried out for each use of this class, where the aforementioned is deepened and other analyzes are added.

6.2.1 Demand Side Management (DSM)/ Demand Response (DR)

6.2.1.1 Opportunities

The growing penetration of NCRE is the main opportunity for these technologies, since their intermittency may require systems to feature flexible resources, hence benefiting from greater control of the demand to guarantee the security of the system.

On the other hand, technological advances in topics such as cloud computing and smart homes (hardware and software) also provide more opportunities for the demand response to be technically feasible.

In addition, applications that have emerged from data science (for example, Big Data) and AI are an opportunity for these technologies because, in addition to improving their operation through machine learning, they also provide a business opportunity through the use of user data that are used for the DSM/DR, provided that this use is notified and accepted by the user.

The aforementioned technologies also mean new opportunities in customer services, such as smart pricing, benefiting users and the market. These new customer services are beneficial to the market, and lead to new business models.

The technologies and innovations in the market that are required for this use bring with them a reduction in the price of energy and a promotion of innovation to optimize DR, in addition to the reduction of service costs thanks to consumption management.

6.2.1.2 Breaches and goals

For the study of breaches, the experience of the UK, Singapore, and South Korea, was investigated.

- UK: In 2016, the non-profit organization Forum for the Future set out to hire 20 organizations in total to meet the goal of generating 200 MW of flexible power by 2020, through a response energy system to centrally controlled demand.
- Singapore: In 2016, Energy Market Authority (EMA) implemented the DR Program to enhance competition in the Singapore National Electricity Market ("NEMS"). Unfortunately, the results were not encouraging: until 2019 there was low participation in the program, mainly justified by low incentives and a minimum acquisition price not very competitive with the uniform price of energy in Singapore. That is why after a complete review of the program, a trial period was determined where different minimum energy prices marketed by the DR will be studied, in order to find

an economically viable proposal. These tests require industry participation for the assessment of regulatory environments.

- South Korea: Korea's second Energy Master Plan is a comprehensive plan that covers all energy sectors providing a medium and long-term vision of energy policy. Among the action plans of the Energy Efficiency axis, there is a list of actions and tariff and tax adjustments that allow establishing a demand management system based on ICT, developing a variety of hourly pricing schemes to incentivize the user to participate in reducing peaks. In addition, the plan proposed the development of energy service companies (ESCO) with EMS (Energy Management System) technologies as demand management aggregators, offering them opportunities to participate in the energy market. This is accompanied by a review of the regulations to allow the energy saved through efficiency improvements to be traded in the energy market, taking into account the progress in bidding on the demand side and the growth of DSM businesses.

6.2.1.3 Barriers

DSM / DR barriers are mainly linked to the complexity of the system both economically (both by the operator and the end customer for expenses such as the smart meter) and technically. The improvements needed to implement these technologies can significantly decrease the speed with which their use becomes effective, which means a significant opportunity cost. Added to this is the need to have meters capable of measuring bidirectional flows with hourly resolution.

User behavior can affect the correct operation of these technologies: an excessive response to demand can generate stability problems in the network, and a low response can affect the adequacy of the system (in addition to not complying with its target as DSM or DR). Furthermore, there could be a low user participation in this type of mechanisms, justified mainly by low economic incentives and uncompetitive prices for the sale of energy to the system. To do this, tariff and tax adjustments are used to establish a demand management supported by ICT, enabling a variety of hourly price schemes that encourages the user to intervene to reduce peaks.

Another barrier is the accessibility of the information, since the participation of users in the market relies on having access to the necessary information. A user will not be able to participate in demand management if they do not have the necessary information to respond correctly to the state of the network. This means a void for users who have distributed resources but not the ability to communicate with the network. This can be critical in rural areas or in areas where Internet access is limited.

There is also a barrier related to the security of the system. Given that massive access to system information is needed by users, it becomes more susceptible to attacks. Hence, the information delivered and the amount of user participation must be limited to avoid threats such as induced blackouts. There is also another barrier linked to information: access to information that can be considered sensitive by the user is a social barrier, which can translate into legal barriers to the implementation of these technologies.

Finally, the development of DSM/DR requires a participatory process where each of the agents can intervene and evaluate the proposed regulatory environment, especially users and the industry. This is key, as the purpose of DSM/DR and the agents' responsibility need to be well defined.

6.2.2 *Energy Storage*

6.2.2.1 Opportunities

Given the intermittency of renewable energies, the necessary ramp capacity in the system will increase: this is an opportunity for energy storage since one of its advantages is the ramp capacity they can deliver. Combined with the coordination ability with the rest of the grid (through digitization), energy storage would significantly increase the reliability of the network. In addition, the decarbonization plans in the different countries usually translate into a greater penetration of NCRE, which provides an opportunity for energy storage. With a high presence of distributed resources, it becomes competitive when seeking to maximize social welfare. In this scenario, it is also beneficial for conventional generators, since their average cost is higher with a high presence of NCRE and without energy storage. The aforementioned economic benefits show that energy storage can also enable new business models, associated with generation / consumption management.

On the one hand, the increase in both the ramp capacity and the penetration of NCRE reduces the operating costs of the system, and reduces the price of energy. On the other hand, they increase the security of supply thanks to the contribution they can make during contingencies, which in turn reduces the grid downtime. For this reason, investments in transmission can also be reduced.

6.2.2.2 Breaches and goals

The cases of UK, Germany and Singapore are analyzed below to determine the gaps at the international level.

- UK: The UK seeks to maximize the use of renewable energy, for which the use of storage is necessary. One of the gaps in this regard is to reach a greater storage capacity. Currently, there are limits imposed for storage projects, which obstacles discourage investment in storage projects, so one of the goals is to eliminate the 50 MW limit for this type of projects in England (GOV.UK, 2020).
- Germany: In Germany it is sought that by 2050 80% of the energy supply will be through renewable energies (currently it is 36%), where the implementation of energy storage is vital for this objective. The gaps in energy storage to support this goal are the need for the massification of EVs (as storage units) and cost reduction, however it is expected that the cost will be reduced considerably by 2035 (50% less cost approximately) (GTAI, 2019). Incentive schemes for investments in storages related to distributed renewable installations are in place.
- Singapore: Singapore has the goal of having 200 MW of energy storage to 2025 (Energy Market Authority Singapore, 2019). This goal is linked to the desired increase in the use of solar energy, lacking geothermal and wind energy. The viability of energy storage considering this goal requires an increase in solar generation in the country, being this goal 2 GW for 2030. The need for technological advances is also mentioned so that the Distributed Energy Storage System is cost effective, for which $15 million have been invested in innovation (Energy Market Authority Singapore, 2016).

6.2.2.3 Barriers

The main barrier in some forms of energy storage (such as batteries) is the high investment cost, so it is currently not competitive compared to the conventional alternatives. However, with the decarbonization plans, energy storage becomes more attractive. Other forms of energy storage, such as thermal, are promising, but are not practical yet (Sylvia, 2020). Another energy storage barrier is linked to the displacement of conventional generation plants. Given that through this technology conventional plants' use will decrease, it can generate problems in the short-term with long-term contracts by generators that will be affected by the implementation of these technologies, possibly raising legal or legislative conflicts. Finally, the regulation and participation of energy storage in some markets are not fully defined.

6.2.3 *Virtual Power Plant (VPP)*

6.2.3.1 Opportunities

The increase in distributed resources in the grid is an opportunity for VPPs. The increase in distributed generation capacity (public or residential) and the presence of microgrids mean that VPPs can compete with conventional generators thanks to their lower equivalent fuel cost. This results in VPP's reduced operating costs of the system.

Given that VPPs are, in simple words, a way of aggregating and coordinating distributed resources, it provides opportunities for the development of other digitalization uses such as microgrids or all the other applications of this category (e.g. energy storage, DSM).

6.2.3.2 Breaches and goals

- UK: Currently 160 MW of capacity are under VPP control, with capacity auctions creating a market worth 50M GBP for demand response aggregators (Enbala, 2019). Some of these VPP are supported by government funds, like Moixa's VPP in Worthing and Shoreham-by-Sea, as they would improve CO_2 emissions reduction (Bairstow, 2019; West Sussex County Council, 2019). The UK has the target to be net-zero emissions by 2050, but no specific target was found related to VPP.

- Germany: The company Statkraft began to work on the very first VPP in Germany in 2012 together with their partner Energy Meteo Systems. Statkraft's VPP is the biggest of its kind in Europe. Today this innovation has been adapted by other players, and now there are probably more than 50 VPP solutions available. Germany is a leader in supply-side VPPs, with up to 650 MW under control. While demand-response is not a key resource currently, there are some initiatives worth noting in the demand-side of VPPs, like the one planned through Sonnen/Tiko, which was qualified by grid operator Tennet.
  Some of Germany's VPP's are supported by blockchain technology. No specific target was found related to VPP.

6.2.3.3 Barriers

Internet quality and access by the resources used for VPPs is a considerable barrier, as connection errors can impair the proper functioning of these plants. On the other hand, the implementation of these technologies involves a high computational cost that could prevent using all the capacity that in theory is considered.

The complexity in legal and/or regulatory terms must also be considered, since these aspects must be adjusted in each country so that the VPPs can participate in the energy market as they are generators that cannot be regulated under the same parameters as conventional generation.

6.2.4 *Distributed Energy*

6.2.4.1 Opportunities

The opportunities of distributed energy are associated with lower costs thanks to technological advances in this application, such as the decreasing cost of solar panels or the implementation of feeder automation and energy storage. All these advances mean system cost reductions that give distributed energy the opportunity to compete with conventional generation. On the other hand, the climate crisis is an opportunity for the adoption of this type of energy production, thanks to its contribution through emission reduction, increasing social welfare. Likewise, consumers who implement this type of solutions receive reductions in their bills (self-consumption), in addition to remuneration for injecting surpluses into the network, as provided by the corresponding regulations. From the point of view of security of supply, having the capacity to generate directly at the consumption points allows to decongest the network and to be supplied in

6.2.4.2 Breaches and goals

In this case, the experience of Germany, China and South Korea was analyzed.

- Germany: During the 2009-12 period, Germany experienced a boom in distributed photovoltaic generation plants, which slowed down as a result of government intervention to control the costs of subsidies. However, the fall in the prices of PV panels has encouraged their adoption. It is even estimated that by 2024 the growth of distributed PV could be 50% compared to 2019. Regardless of this, it is desired to put more focus in policies for distributed renewables, including regulatory frameworks aimed at a fair allocation of infrastructure costs (e.g. distribution grids, smart meters) that can enable distributed renewable generation and flexibility resources, such as response on the demand and storage side.
- China: In the case of China, its economic structure dependent on the commercial sector presents a demand for more distributed energy, office complexes and small industrial facilities. On the other hand, the 13th Five-Year Plan (FYP) has several technology objectives that constitute the basic components of distributed energy systems (DES). The natural gas installed capacity target is 15 GW of distributed natural gas (DNG) projects out of a total target of 110 GW of natural gas electricity generation capacity. Photovoltaic solar energy will be the backbone of the deployment of distributed renewable energy during the 13th FYP Plan, reaching the planning goal of 60 GW of distributed solar energy by 2020, out of a total photovoltaic solar energy goal of 105 GW. Many local governments have also issued supportive policies to reduce air pollution and increase energy efficiency (This is favored by the energy distributed as it generates less pollution compared to a large part of conventional generation)..

- South Korea: Korea's second Energy Master Plan is a global plan that covers all energy sectors providing a medium and long-term vision of energy policy. On the renewable energy axis, the need to expand distributed generation stands out. It is expected to supply more than 15% of the energy from distributed sources, such as integrated power systems, renewable energy and local generators by 2035.

6.2.4.3 **Barriers**

The inclusion of distributed energy has regulatory barriers associated with tariffs. Since clients would also participate as generators, the way in which they are priced, and their market share must be adjusted. In countries where this technology is more mature, the necessary regulation is in place, but the more it becomes widespread, the more complications it will generate, mainly with generating companies and their profits. Likewise, a public policy that provides subsidies for the incorporation of distributed generation can encourage its adoption, accompanied by regulatory frameworks for a fair allocation of infrastructure costs. If support from local authorities is added to the above, the incentive is even greater.

The upgrade of electrical systems is an important barrier for distributed energy. The change from one-way to two-way power flow -as well as a considerable investment cost- can generate problems such as congestion in the transmission or distribution systems, or increased costs associated with losses, if the integration is not coordinated (for example, through Smart Grid applications and technologies). On the other hand, the amount of information that must be handled is also a limitation to consider, because despite having a large distributed energy capacity, it must have the necessary computing resources (which could imply more costs than benefits from distributed energy). In addition, there is the risk of losing the ability to coordinate with a large number of participants, as well as technical problems associated with an over injection of energy towards the grid. Guidelines to design future energy systems will be necessary to face all these barriers.

In regulatory terms, there may also be non-compliance due to the need to create laws and regulations to avoid problems in the operation of the system.

6.3 Customer domain

This type of uses encourages the active participation of citizens and organization in existing or new energy markets. By doing so, these uses can contribute in terms of flexibility and energy balance of the systems, and to the promotion of renewable energy sources. They also could lead to an improvement in the user experience, through a feeling of closeness and transparency on the part of the energy companies. These uses are highly related with demand side management, and smart grid.

Two uses are analyzed in this section, the first one “Prosumers and P2P” is related to digital applications that enable end users to sell energy products back to the grid. Such type of end users are the *prosumers* and, when these products are exchanged between end users, the exchange is called *peer-to-peer* (P2P). Digitalization is key to this use as it can be employed to remotely measure the energy product, which can be time-specific, through AMI. This application can be used to trace the origin and consumption of the energy product through blockchain or can enable the trading within prosumers through a digital marketplace. The second use, “Retailing, billing and customer orientation” is related to activities in the retail energy market, in which digital applications can be leveraged to improve the customer experience from part of the retail company. Here, important digital infrastructure must be in place to ensure privacy of customers’ data while providing access to retail companies in order to bill their customers. Other digital applications in the second use are those aimed to give information and transparency to users about the retailers deals, such as online price comparison tools.

6.3.1 *Prosumers and Peer-to-peer (P2P) trading*

6.3.1.1 **Opportunities**

This use encourages the participation of citizens in existing or new markets, to contribute in terms of flexibility or balance, from an economic point of view. This use is highly compatible with other uses related to the engagement of the population, such as DSM or DG.

6.3.1.2 **Breaches and goals**

The goals associated to this use are mainly oriented towards the participation of agents. Below are the cases of France, Germany and Swedish.

- France: France as part of the EU encourages the entry of prosumers to the market. However, in order to generate a real impact on the network, in addition to ensuring that the system operators will not be affected, the participation of a large number of consumers must be fostered. The lack of participation is the main gap for the goal of the entry of prosumers to the market, which seeks to be solved with incentives through taxes, fees or the promotion of others that complement this, such as energy storage (European Economic and Social Committee, 2016).
- Germany: In Germany there was legislation that promoted the entry of prosumers such as the "Tenant Supply Act" (Energy Democracy, 2017), but then it has stagnated in the goal of energy transition from the field of prosumers. In order to move towards a more modern energy matrix, there are important gaps such as the improvement of the feed-in-tariff (nowadays it is decreasing), or upgrades to the "Act on the Digitization of the Energy Transition" which obliges users to generate more than 1kW with solar energy to install a smart meter on their own (barrier). These necessary upgrades are the main gap between the current state of prosumers and the desired state, where there is greater participation by small users.
- Swedish: In Sweden there are policies that seek to encourage the participation of prosumers. However, this increase in participation by prosumers must overcome certain gaps, such as the lack of a clear objective or an increase in the limit of 255kW for the tax exemption (SolarPower Europe, n.d.)..

6.3.1.3 Barriers

- Dependence on an internet connection is recognized as a barrier. Furthermore, given the nature of the data that is traded, a highly secure system is required, which translates into higher complexity and cost.
- This application involves a thorough understanding from the population, so that they are confident to access and use of this type of exchange.
- The sovereignty of the information processed must be determined and who or whom would have access to said information must be defined.
- There must be a cybersecurity system capable of dealing with possible attacks.
- A greater participation of the population as agents is needed to generate a measurable impact from this use.
- Updating the laws that encourage this participation is often required.

6.3.2 *Retailing, billing & customer orientation*

6.3.2.1 Opportunities

This use entails an improvement in the user experience, through a feeling of closeness and transparency on the part of the electricity companies.

6.3.2.2 Breaches and goals

No specific targets were found for this use, but there is information about the current state of the energy retailing and actions taken in order to improve market competition.

- Singapore: Since 2001, the Energy Market Authority (EMA) has progressively opened the retail electricity market to competition (Energy Market Authority Singapore, n.d.). This is to allow consumers to enjoy more choices and flexibility when buying electricity. Consumers will also benefit from competitive pricing and innovative offers while enjoying the same electricity supply. The Open Electricity Market marks the final phase of market liberalization efforts where all consumers in Singapore can choose who they wish to buy electricity from. Their options are to buy electricity from: (i) An electricity retailer at a price plan that best meets their needs; or (ii) The wholesale electricity market at half-hourly wholesale electricity prices through SP Group; or (iii) (Default) SP Group at the regulated tariff. The Open

Electricity initiative includes digital services oriented to help users to make informed decisions, for instance, an online price comparison tool (Open Electricity Market, n.d.).

- UK: Full competition was introduced into Britain's electricity retail market in 1999. Since then, domestic and non-domestic consumers have been able to shop around for their electricity supplier. The six largest firms in the GB retail market are Centrica, EDF, E.ON, npower, ScottishPower and SSE. They are the former monopoly suppliers of gas and electricity to UK consumers and together they now account for around 70% of the retail energy market (Ofgem, 2019). In 2017, the Competition and Markets Authority (CMA) introduced a Price Transparency Remedy (the Remedy) which aimed to improve energy price search and comparison processes for microbusinesses (Ofgem, 2018), and in January 2019 was introduced a retail price cap to provide price protection to around 11 million customers on expensive default energy deals. On implementation, is estimated that the cap has saved customers £1 billion.
- France: Since the French electricity and natural gas markets were fully opened up to competition on the 1st of July, 2007, consumers have been free to choose their energy supplier (Commission de régulation de l'énergie, 2018). As a result of deregulation, suppliers other than the incumbent operator, who are known as "alternative" suppliers, entered the retail electricity market. As of 30 June 2018, 78% of residential and non-residential sites were paying the regulated tariff, with 22% paying market rates (20% with alternative suppliers). About 36% of electricity used was supplied at the regulated tariff, with 64% supplied at market rates (33% with alternative suppliers). The non-residential market is much more open (36% of sites pay market rates) than the residential sector (where just 19% of homes pay market rates).

6.3.2.3 **Barriers**

The first barrier for this application is the regulatory framework. The reforms must be tailored to the reality of each country in order to ensure competition in the retail energy markets. The second barrier is information security, as the treatment of large amounts of private data must be secured.

6.4 Process Management

This section addresses the analysis carried out on the uses whose objective is to improve the processes associated with the generation and / or consumption of energy, including each of the associated internal processes. Consequently, the incorporation of these uses entails an improvement in the efficiency of the processes through the deployment of equipment and technology, which usually comes with a high investment cost. The implementation of process optimization and automation (gas, oil and coal) and emissions monitoring are explicitly analyzed.

6.4.1 Process optimization & automation

6.4.1.1 Opportunities

The incorporation of this use entails an improvement in the efficiency of the processes through the deployment of equipment and technology. The optimization of production processes could lead to an increase in the satisfaction levels of employees and the creation of new job profiles (as a counterpart to the elimination of other positions). The benefits related to Robotic Process Automation (RPA), which corresponds to the use of software bots to automate highly repetitive, routine tasks normally performed by knowledge workers, are identified in (Deloitte, 2019) and (IBM, 2020): Reduction of operational costs for tasks that are repeated very frequently, to reduce human errors in manual activities[2], facilitate continuous productivity throughout the day, improve customer experiences, among others.

6.4.1.2 Breaches and goals

In this case, a specific analysis of the Singapore case and a general analysis of various experiences at the international level are presented.

- Singapore: Energy Story is a program of the Singapore Ministry of Commerce and Industry, which aims to work towards a future where energy is reliable, efficiently produced and consumed. One of its 4 lines of work is related to the optimization of the electric power generation process using gas as a source, in order to improve the efficiency of the processes through the deployment of equipment and technology. The above considering that today, around 95% of Singapore's energy is generated with natural gas.
- The document "Intelligent Automation in Energy and Utilities: The Next Digital Wave - Global Automation Research Series: Energy and Utilities" (Capgemini, 2019) presents a review about the advancement of digital applications that some organizations have taken globally and the challenges they have faced. In addition, good practices based on performance are recognized, which allows describing some recommendations to drive intelligent automation at large scale. Examples of optimization and process automation mentioned in the paper include:
  - Xcel Energy (electric and gas utility in US) uses sensor data in wind turbines to develop high-resolution wind forecasts through predictive analytics and artificial intelligence, thanks to which it has been able to reduce costs for end customers by $ 60 million as a result of the increase in generation efficiency;
  - NextEra Energy (American energy company Fortune 200) applies machine learning to optimize the operating parameters of its fleet of wind turbines, with the aim of maximizing production and performing predictive maintenance, obtaining a reduction of between $ 3 to $ 4 per MWh;
  - Total (French Oil and gas major) is working together with Google Cloud on the analysis of subsurface data for oil and gas exploration and production using AI.

  The document reflects on the resistance that people could have to automation initiatives, for which it recommends that their incorporation be carried out in an informed manner, since in practice 78% of leading companies on the subject say that automation has increased satisfaction levels of their employees and 66% say they have created new job profiles, which counters the fact that 71% also say it has led to downsizing. It is also recommended to accompany transition with programs that improve job skills.
- According to (McKinsey, 2019), more than 81 percent of predictable physical work, 69 percent of data processing, and 64 percent of data-collection activities could feasibly be automated. In (European Commission, 2018) it is stated that AI could contribute up to EUR 13.33 trillion to the global economy in 2030. In addition, AI should have the potential

to cut 10% in national electricity usage by using deep learning to predict power demand and supply. Machine learning could also yield 12% fuel savings for manufacturers, customers and airlines by optimizing flight routes.

6.4.1.3 Barriers

There is a high investment cost associated with the implementation of this use, which is mitigated by the excellent economic benefits it provides. In (Deloitte, 2019) the main two identified barriers are the process fragmentation of the daily activities and the IT readiness of infrastructure and systems.

It is likely that there is resistance from employees that companies include automation initiatives, so it is recommended that their incorporation be carried out in an informed way and accompanied by programs that improve work skills.

With regard to the use of more advanced techniques such as machine learning and artificial intelligence in process automation, the following barriers are identified at (McKinsey, 2019) in European companies: first, barriers relates to the ability to use Information and Communications Technology tools in work place and, the second barrier relates to companies' need for skills to provide new AI applications and services.

Economic, technical, and social barriers for the adoption of AI are identified in (Cubric, 2020) based on the literature review of 30 reviews published between 2005 and 2019:

a. Economic: prohibitive cost of implementation and maintenance, the need for supporting infrastructure;
b. Technical: lack of useable data, non-reusability of models, limited applicability for some class of problems;
c. Social: increased dependence on non-humans, job security fears, lack of knowledge and understanding of potential benefits, safety issues, lack of trust and difficulty in obtaining multiple stakeholder perspectives.

6.4.2 *Emissions monitoring*

6.4.2.1 Opportunities

A good measurement and constant monitoring of emissions for a certain process, facilitates decision-making and mitigation actions according to the situation and context.

6.4.2.2 Breaches and goals

The goals associated with this use are analyzed for the cases of UK, USA and Japan, set out below.

- UK: The goal behind this use is the reduction of emissions, in the United Kingdom its emissions will be reduced to zero by 2050 (GOV.UK, 2019a), emission monitoring becomes relevant in verifying that the objectives are being met. The gap to overcome to achieve this objective in the energy sector is the reduction of conventional generation. On the other hand, it is inferred that a better management of uncertainty is also a gap to achieve the desired results with emission monitoring (GOV.UK, 2019c).
- USA: In the United States, this use is part of the goal of emissions reduction. For that purpose, the US Environmental Protection Agency (EPA) created the Emission Measurement Center (EMC): Continuous Emission Monitoring Systems (which is a system associated with this use). Despite having this tool (US EPA, n.d.) it is still in the process of reducing emissions and there is a large gap to achieve the desired state, this is, the need to reduce the large number of current emissions in the country, which are intended to be zero in 2050, and which goes hand in hand with a massification of this use for regular emissions.
- Japan seeks to reduce emissions to zero by 2050 (Sasakawa USA, 2020). Just as the United States, Japan has a continuous emissions monitoring system to support the fulfillment of this goal. The gap for this goal is the large amount of emissions remaining to be reduced. In line with this, it is commented in (Eco Analysis Corporation, n.d.) that despite having emission monitoring systems, the main gap for the objective of this use is the need for a change in people's behavior and business ethics.

6.4.2.3 **Barriers**

The lack of economic incentives for the main emitters of pollutants can slow down the implementation of this use. Linked to this, the high cost of modernizing monitoring systems is also a barrier, in addition to not being able to access all the necessary information.

6.5 Mobility

The digital transition in mobility may increase the overall customer satisfaction in urban areas by reducing traffic time, which also reduce the emission of GHG. Other benefits of smarter, cleaner and more connected vehicles is the increased safety for people as it reduces the probability of accidents caused by human errors. The climate crisis has generated an urgent need to reduce emissions, with connectivity, applications can be developed for advanced transport systems such as: remote fleet monitoring, coordination systems based on communications, algorithms and applications that help users to have better (transport) connections in their trips, collection and processing of data (from sensors and other information systems) to provide dynamic responses in transportation services. Although the mentioned applications are oriented to transport, their implementation will result in lower emissions and a more efficient use of fleets.

Mobility class is separated in four different domains: transport for personal use, public transport, transport cargo, and shared mobility. Many digital applications are applicable to more than one domain; for instance, fleet management and monitoring is highly compatible with public transport, transport cargo, and shared vehicles; Advance Driver Assistance Services (ADAS) are employed in all four domains; smart charging applications can promote the use of personal and shared electric vehicles; smart intersections based on vehicular traffic and pedestrians' detection is applicable to all four domains, and so on and so forth. In the upcoming digital era envisioned for intelligent transportation system, connected vehicles (i.e., vehicles exchanging information with other vehicles, other road users, and external networks), and autonomous vehicles become the most influential enabling technologies to unleash innovative digital mobility-related applications. Since several digital applications belong to more than one domain, part of the analysis of opportunities and barriers is applicable to more than one domain at a time.

In terms of connected vehicles and smart road infrastructure, the implementation of 5G and other technologies such as IEEE 802.11p, together with the massification of IoT, offer opportunities to accelerate the digitalization in mobility solutions, which also foster innovation and new business models. Recent advances in mobility have brought concepts such as the ACES (automated, connected, and electric) vehicles, with focus on automation and connected vehicles. By connecting vehicles with wireless communications, it helps creating a cooperative transport system, useful to avoid bottlenecks and traffic accidents, improving comfort of drivers and passengers, and bringing an overall improvement to the safety of the roads. In the policy side, countries are putting efforts into electrification of the transport, making it also more connected and improving access to information for users. All these advances impose several challenges in terms of modern regulation, in the generation of proper incentives to foster the adoption of new technologies, in the creation of mechanisms to preserve privacy of personal data, and in the procurement of security of the cyber-physical networks.

6.5.1 Transportation for personal use

6.5.1.1 Opportunities

The digital transition in this use may increase the overall customer satisfaction in urban areas by reducing traffic time with implementation of vehicular networks and coordination systems, which also would reduce the emission of greenhouse gases. Smarter, cleaner and more connected vehicles for personal use could be safer for people as it reduces the probability of accidents with the development of autonomous vehicles and advanced driving assistance systems (ADAS). The integration of intelligent transportation systems (ITS) to smart grids, distribution systems, and charging stations networks can provide additional benefits for users of personal electric vehicles: Income from participating in the complementary services market (V2G service), increased resilience of the electricity distribution network (V2G service), and detailed information on the availability of charging stations and rates(Smart charging networks). In addition, system operators can more accurately access data on the sharing of electricity demand associated with electric vehicles.

Table 10 lists a set of digital applications in this domain and the opportunities identified.

Table 10: Opportunities for transportation for personal use

Digital application	Opportunities
Home-to-car convergence: managing the vehicle as another appliance of the house. It means the car "talks" to the house	Integration of car as a digital service with open market to related apps

Digital application	Opportunities
to trigger events, synchronize personal applications, and to program recharging sessions for electric cars, among others.	
Cooperative ADAS: assistance to the driver based on sensor information and motion information received by nearby vehicles: collision avoidance, lane-changing, lane-merging, surrounding object detection, etc.	Improving safety Reducing gas emissions
Cooperative intersections: coordinated intersection crossings based on the motion information shared by vehicle instead of static traffic signals. It is the evolution from actuated traffic lights.	Reducing travel times Reducing gas emissions Improving safety for vehicles, pedestrians, and other vulnerable road users
Remote monitoring from car manufacturer	Reduce the impact of usage related failures. Improve safety. Predictive maintenance Use of sensor data to improve car manufacturing processes
Applications based on vehicle-to-grid communications	Enable vehicles to provide services Planning of optimal deployment of charging stations Tracking of battery consumption for predictive actions
Advanced Navigation with augmented reality and computer vision	Improve navigation user's experience Route optimization Reducing gas emissions
Charging network applications: applications that enhances the use of charging stations.	Opportunities for people to reach payback for their own charging station investment quicker (P2P schemes). Better user experience for EV drivers. International roaming with national rates.

6.5.1.2 Breaches and goals

One breach for applications related to electric vehicle would be the adoption of these new type of vehicles and technologies.

The Korean New Deal determines that by 2025 there will be 1,130,000 electric cars and 200,000 hydrogen fuel cell cars circulating throughout the country.

In UK, the "Road to Zero" strategy has 17 of its 46 policies focused on "supporting the development of one of the best infrastructure networks for electric vehicles in the world", all this to give the autonomy that users demand. The areas where the government will intervene to support the development of charging points is through the planning process and through certain grants, but private financing will be privileged. The Road to Zero's goal is for all new cars to be electric by 2040, even though there is pressure to meet it by 2030. On the other hand, these incentives for the adoption of EV must be accompanied by a review of the regulation and tax aspects, especially, the electricity tax paid by companies (20%) and households (5%). From the operational point of view, National Grid mentioned that so that the mass adoption of EVs does not mean a problem, the load needs to be carried out flexibly, including technologies such as V2G in its implementation, even for a prediction scenario of up to 11 million electric vehicles by 2030 and 36 million by 2050.

The French National Assembly passed the long-time coming Mobility Orientation Law. This new legislation seeks to make everyday transport more accessible, better adapted to the diversity of needs, and cleaner. The challenge for this law was to "clarify the distribution of powers between public stakeholders, while dealing with the increase in private companies entering the new mobility market" (Futura-Mobility, 2020). Some of the key points related to transportation for personal use in this law are: 1) The regulation of Data exchange and Mobility as a Service (MaaS), 2) supervision of free-floating services (shared vehicles without fixed stations), 3) legal framework for autonomous vehicles, 4) the possibility of introducing dedicated lanes for "extremely low emission vehicles", and 5) supervision of carpooling. It also set the objective of decarbonizing land transport. It proclaims a ban on sales of passenger cars and light commercial vehicles running on fossil fuels (petrol, diesel, natural gas, etc.) by 2040. And the outlaw of these vehicles from the roads by 2050.

6.5.1.3 **Barriers**

In terms of connected vehicle technology, several barriers are identified that are both regulatory and technological, and that impact different means of transportation for personal use: regular vehicles that benefit from cooperative ADAS, electric vehicles, and autonomous vehicles (and the combinations therein). The interoperability and standardization issues seem like the principal technological barrier, for both physical and digital interfaces. The barriers identified are the following: a) a low market penetration of vehicles equipped with connected vehicle's technology; b) a lack of consensus about the technology to be massively adopted by vehicle manufacturers. This refers to the competition between two leading V2X technologies: IEEE 802.11p/bd and 4G / 5G, which has also derived in a competition for spectrum allocation in the USA; c) a lack of regulation that imposes the mandatory incorporation of wireless connectivity in vehicles, to enable the use of road safety applications based on vehicle-to-everything (V2X) communications. In the USA, starting 2020, all new vehicles were going to be equipped with V2X technology as mandatory, however, the Trump administration overthrew the proposal and delayed the deployment of such a technology in new cars; and d) the cost of incorporating V2X technology in vehicles is still high (around US $1500 to US $2000 per unit as of 2020).

In terms of autonomous vehicles, the barriers are mostly regulatory: several laws need to be updated to account for a machine being the driver of a personal car. Such a consideration may require a major reform of the legal framework that supports the operation of private transportation, including civil and penal responsibilities that involve not only the owner of a vehicle but also the car manufacturer that programs and maintains the "virtual" drivers in every car.

Other challenge worth mentioning about the massification of electric vehicles and digital applications in charging technologies (V2G services, shared charging network, aggregation of EV demand, etc.), is the technical operation of distribution grids (and even planification of transmission expansion) with high penetration, and time concurrency, of EV charging and the actual capacity of domestic circuitry to withstand the currents needed by the charging infrastructure.

6.5.2 *Public transport*

6.5.2.1 **Opportunities**

There are different digital applications that could help improve the quality of public transport and with this increase the public preference for these means of transport: remote monitoring of fleets, coordination systems based on communications, algorithms and applications that help users to have better interconnections (transport) in their travels, collection and processing of data (from sensors and other information systems) to provide dynamic responses in transport services (for example, dynamic routing to better response to contingencies), smart payment systems, digital applications (AI cameras) that help to monitor the use of exclusive roads for public transportation and fine those who violate them. For the case of electric bus transport, there are applications that allow optimizing the battery recharging periods (charge scheduling). All these applications could help improve the experience of using public transport, know more precisely the travel times, optimize the energy use of public transport and increase the participation of this mode of transport.

Although these applications are oriented to transportation, their implementation will result in lower emissions if they are applied in fleets of traditional fuels or in the efficient use of electric fleets.

Table 11 lists a set of digital applications in this domain the opportunities identified.

Table 11: Opportunities for public transport

Digital Application	Opportunity
Remote monitoring of fleets	Better information source to improve operations and for predictive maintenance purposes.
Remote operation: control and driving of public vehicle via telemetry and virtual reality	Less exposure from operators and drivers Address labor shortage
Cooperative ADAS: assistance to the driver based on sensor information and motion information received by nearby vehicles: collision avoidance, lane-changing, lane-merging, surrounding object detection, etc.	Improving safety. Reducing gas emissions.

Digital Application	Opportunity
Cooperative intersections: coordinated intersection crossings based on the motion information shared by vehicle instead of static traffic signals. It is the evolution from actuated traffic lights.	Reducing travel times Reducing gas emissions Improving safety for vehicles, pedestrians, and other vulnerable road users.
Dynamic routing: Automatic assigned routes for public vehicles concerning traffic state	Better response to contingencies and changes in demand patterns. Reducing travel times. Reducing gas emissions.
Smart payment systems: Flexible digital payment options for public transport	Better control of ticket evasion and greater interoperability within public transport options.
AI powered cameras: digital cameras with AI capabilities installed on public fleet.	Better control of ticket evasion and exclusive road usage.
Smart charging scheduling: Automatic charging/discharging dispatch for electric fleet.	Use of electric fleet as a flexibility resource for the grid and optimize the charging cost of vehicles.
Cooperative ADAS: assistance to the driver based on sensor information and motion information received by nearby vehicles: collision avoidance, lane-changing, lane-merging, surrounding object detection, etc.	Improving safety Reducing gas emissions
Cooperative intersections: coordinated intersection crossings based on the motion information shared by buses instead of static traffic signals. It is the evolution from actuated traffic lights.	Reducing travel times Reducing gas emissions Improving safety for public transport, vehicles, pedestrians, and other vulnerable road users
Applications based on vehicle-to-grid communications	Enable vehicles to provide services.

6.5.2.2 Breaches and goals

In Singapore, the Smart Mobility 2030 Strategic Plan wants to reduce the number of car and increase the public transport. This plan includes the use of Big Data and smart traffic management.

For the electric public transport, the gaps in this use are associated with the infrastructure and its costs, investments in charging stations and the adequacy of the existing infrastructure can limit the advancement of these technologies. Specifically, the experiences of Germany, the United Kingdom and France were analyzed. The European Commission and the German federal government have promoted an electrification plan for the transport system whose joint financing reaches 1,850 million euros until 2031. This in order to meet the environmental objectives of the EU and the nation, through the promotion of the use of public transport. This injection of money will not only allow the purchase of new electric and hybrid trains and buses, but also for the creation of charging infrastructure throughout the country and the reconstruction of the railway system. In addition, it is proposed to economically incentivize users to prefer public transport over private, through a reduction in the rates for the use of public transport and taxes for highly polluting cars. In UK, the British government has launched a program that authorities can apply to become the UK's first fully electric bus city. The winning area had up to £ 50 million to help pay for a new fleet of electric buses, reduce emissions and clean the air in their community. The £ 50 million fund is part of a total of £ 170 million allocated today to improve services and make bus travel greener, easier and more reliable. In France, there is a government initiative that aims to improve public transport connections in rural areas of the country where people are forced to use their cars due to the lack of public transport, which proposes measures to create more transport options and that they are cleaner. The law also proposes that there would be comprehensive access to information on transport solutions, schedules and rates, both in the city and in the countryside. At the end of 2021, a platform will be made public that offers information on the transport networks in France, including for cyclists, train and bus passengers and people who share the car. The proposal also includes a reduction in driver's license associated with participation in carpool or cycle programs. Also, it is proposed that employers pay their staff a bonus for using more sustainable transportation methods. This initiative even incorporates the legal framework for the integration of autonomous buses.

6.5.2.3 Barriers

About vehicle connectivity, similar barriers to transportation for personal use are identified. Regarding the policy making, regulations must promote transport modes and applications that benefits society, incentives in vehicles for personal use may result in costlier public transport for low income segment of the population.

6.5.3 Transport cargo

6.5.3.1 Opportunities

The use of digital applications to optimize logistics and automation of trucks will have a significant impact on reducing operating costs in this sector. In (Pernestål et al., 2019) it is estimated that automated and driverless vehicles for road freight transport could reduce cost by 15-30% in comparison to conventionally driven trucks. In addition, the incorporation of technologies related to electromobility in this application would imply a significant reduction in GHG emissions. Given the size of this type of transport, its effects are considerable. On the other hand, considering that freight transport can be scheduled, the intelligent transport network (ITS) can be combined with the smart grid so that users know when it is convenient to carry out transport or recharge their vehicles (for example, not traveling in hours where demand is peak and deliver energy to the grid). The aforementioned ITS can also be favored by the IoT, or Big Data, facilitating remote monitoring or data management for the scheduling of trips and their interaction with the electricity grid.

Table 12 lists a set of digital applications in this domain and the opportunities identified.

Table 12: Opportunities for transport cargo

Digital application	Opportunities
Remote operation: control and driving of personal vehicle via telemetry and virtual reality	Less exposure from operators and drivers Addresses the Address labor shortage Energy cost savings due to lighter vehicles (i.e., driverless)
Cooperative ADAS: assistance to the driver based on sensor information and motion information received by nearby vehicles: collision avoidance, lane-changing, lane-merging, surrounding object detection, etc.	Improving safety Reducing gas emissions
Cooperative intersections: coordinated intersection crossings based on the motion information shared by vehicle instead of static traffic signals. It is the evolution from actuated traffic lights.	Reducing travel times Reducing gas emissions Improving safety for vehicles, pedestrians, and other vulnerable road users
Remote monitoring from cargo fleet manufacturer	Predictive maintenance purposes and others Timely detection of systematic failures
Truck platooning with connected vehicles and automated driving	Reducing fuel consumption and CO2 emissions Improving safety Optimizing transport with efficient road use
Smart charging scheduling: Automatic charging/discharging dispatch for electric fleet.	Use of electric fleet as a flexibility resource for the grid and optimize the charging cost of vehicles.

6.5.3.2 Breaches and goals

This use contributes to the goal of achieving zero emissions associated with mobility where transport cargo contributes. The gaps associated with this are its greater adoption in the system, for which greater charging capacity and better performance batteries are required. Examples such as the case of Sweden, where there is the smart city Sweden program, which promotes the elimination of fossil fuels and a greater charging capacity, or UK where the goal is to have zero emissions by the year 2040, are reviewed below.

- Sweden: The smart city Sweden program has within its elimination of the use of fossil fuels in mobility (Smart City Sweden, n.d.-a), where the use of "transport cargo" enters, and the gap to meet this goal is to achieve a greater charging capacity of electric vehicles, for which projects of wireless electric roads are being developed (useful for transporting loads in long distances) (Smart City Sweden, n.d.-b).
- UK: In the United Kingdom, the goal is that its vehicles have zero emissions by the year 2040, currently working on this objective but there are gaps to meet it, some of them are the development of high-performance batteries and charging infrastructure (very relevant for cargo transport, which makes long journeys) (GOV.UK, 2019b).
- USA: an exact goal is not established in terms of transport cargo or EVs, however gaps are mentioned so that this use is part of the system (Accenture, 2014). For cargo transportation to mature in the USA, new market strategies are required in electromobility, considering the participation of several players, such as owners of cargo infrastructure or mobility providers (for example, providers of cargo transportation services).

6.5.3.3 Barriers

The high cost of vehicles with these technologies is a barrier for this use to enter the market considerably, considering that companies that use transport cargo already have usable fleets. On the other hand, the infrastructure necessary for the creation of a transport network that allows cooperation with the smart grid also involves high costs (remote monitoring, algorithms to optimize transport, updating fleets for transport cargo, etc.), in addition to barriers regulations on the participation of transport vehicles in the electrical network as part of complementary services.

6.5.4 *Shared mobility*

6.5.4.1 Opportunities

The climate crisis has generated an urgent need to reduce emissions, and shared mobility can be a significant contribution if it is used massively. Considering that most of the vehicles that are involved do not use fuel (EV, bikes, scooters, etc.), the reduction of emissions that it delivers by reducing fuel consumption is an opportunity for the insertion of shared mobility, from a perspective both environmental and social. In addition, the opposition to the use of public transport due to COVID-19 will generate an increase in the use of private transport, opening more spaces for shared mobility even after the pandemic is over, also considering that it has the advantage of not having to invest in a particular vehicle. On the other hand, this change in the mobility industry also gives rise to new business models (like Uber, Awto or Mobike). Acording to (SAE, 2020), shared mobility involves not only carsharing, but also bikesharing, microtransit (i.e., private or publicly operated), ridesharing, ridesourcing, and scooter sharing.

Table 13 lists a set of digital applications in this domain and the opportunities identified.

Table 13: Opportunities for shared mobility

Digital application	Opportunities
Remote operation: control and driving of personal vehicle via telemetry and virtual reality	Less exposure from professional drivers Address labor shortage Energy cost savings due to lighter vehicles (i.e., driverless)
Mobility tracking apps: tracking of traveler speeds, direction, travel times, tcl.	Improving safety Improve distribution of shared cars
Peer-to-peer sharing aps: sharing of private vehicles to other users for a fee	Reducing car ownership by using the existent private fleet more efficiently Reducing gas emissions
Ridesourcing applications: platform for sourcing rides (e.g., Uber, Cabify).	Flexible fares based on demand of routes and traffic state
Free-floating vehicle applications: platform for renting vehicles with no fixed point of return.	Promotion of ultra-low emission vehicles (like bikes). Potentially it can reduce vehicle ownership in the city (reduce the need to own certain vehicles).

Trip aggregator applications: Routing of users based on trip aggregation	Reducing fuel consumption and CO2 emissions Optimizing transport with efficient road use
Remote monitoring of fleets	Better information source to improve operations and for predictive maintenance purposes.

6.5.4.2 Breaches and goals

- Germany: In Germany, the number of people using car sharing has grown rapidly in recent years. As of January 2018, there were 2,110,000 customers registered with 165 car-sharing providers in 677 different German cities and communities. Compared to the previous year, 80 additional cities and communities now offer car sharing. In absolute numbers, Berlin is the city with the most car-sharing cars. There are no specific overall goals tied with shared mobility, but its development may have impact on public health since carsharing potentially triggers a multi-modal transport pattern, where walking or using a bike is more likely. Shared mobility also may impact in social cohesion as it could increase social interaction, especially in peer-to-peer sharing. And car-sharing can have several positive or negative environmental impacts, due to the composition of the car-sharing fleet, changes in car ownership and respective implications for the modal split or total demand for mobility (Circular Impacts, 2018).
- UK: Shared mobility is considered in UK's "Future of Mobility: Urban Strategy" (Department for Transport UK, 2019). This strategy is built upon nine principles: 1) New modes of transport and new mobility services must be safe and secure by design. 2) The benefits of innovation in mobility must be available to all parts of the UK and all segments of society. 3) Walking, cycling and active travel must remain the best options for short urban journeys. 4) Mass transit must remain fundamental to an efficient transport system. 5) New mobility services must lead the transition to zero emissions. 6) Mobility innovation must help to reduce congestion through more efficient use of limited road space, for example through sharing rides, increasing occupancy or consolidating freight. 7) The marketplace for mobility must be open to stimulate innovation and give the best deal to consumers. 8) New mobility services must be designed to operate as part of an integrated transport system combining public, private and multiple modes for transport users. 9) Data from new mobility services must be shared where appropriate to improve choice and the operation of the transport system. Currently the adoption of shared mobility alternatives is growing. The number of car club members across the UK increased almost eight-fold between 2007 and 2017, to nearly 250,000 members. Whilst around three-quarters of these are in London, there is growth in many parts of the UK. Innovative services that sit across the boundaries between buses, taxis, and private hire vehicles are challenging the structure of their regulations. The strategy aims to implement a flexible regulatory framework, and efficient, accessible, and safe shared mobility will form an essential part of the future transport network.

In addition to Germany and UK, France has acted addressing shared mobility. "The Mobility Orientation Law" described in the breaches of "Transport for personal use" affect shared mobility directly (Futura-Mobility, 2020).

6.5.4.3 Barriers

The need to connect vehicles and users to the internet represents a barrier due to the increased complexity that this digitization implies in vehicles. The high cost of implementing microcontrollers to bicycles or scooters adds one more dimension that must be carefully addressed, as the reduction of energy consumption and cybersecurity must be considered. In addition, laws and regulations associated with the entity responsible for the vehicle, insurance, technical reviews, etc. must be defined. As long as this is not well defined, the implementation of shared mobility will be an uncertain and insecure issue, discouraging the participation of clients and investors. This gap is similar to the difficulties that Uber has had in Chile.

On the other hand, its implementation may be affected by a social gap associated with mistrust for this service due to questions such as: Is it safe to drive a car that I do not know? In what conditions did the last person who used it leave it? Are they spying on my location?

6.6 Data Management

In this section we study the opportunities, gaps and barriers recognized at the international level, for those uses oriented to data analysis. With these uses, it is expected to operate in a more adequate way, finding the optimum points of operation and maintenance, adjusting to the conditions of the environment. Although today it is possible to implement this type of use, it is emphasized that to achieve a high implementation it is necessary to have a greater adoption of technologies (and advances in them) that complement this use, such as the acquisition of real data. time, or the use of AI.

In particular, the implementation of predictive maintenance and forecasting & predictions is discussed.

6.6.1 *Predictive maintenance*

6.6.1.1 **Opportunities**

Predictive maintenance brings with it a significant cost reduction, on the other hand, it also increases supply security by optimally managing equipment maintenance.

6.6.1.2 **Breaches and goals**

The gap analysis for this use is performed for the cases of Germany, UK and Singapore.

- Germany: Predictive maintenance is part of Germany's digitization agenda (BDEW, n.d.), within the category of digital services, in which it is mentioned that the gap to reach digitization of products and services is a new corporate culture and a greater capacity for innovation.
- UK: In the United Kingdom, maintenance is part of the innovations with artificial intelligence, in National Grid the possibility of using new technologies for maintenance is mentioned, the gap for their implementation is a greater presence of these technologies (which requires investment) and other related technologies such as technologies for data acquisition in real time (mainly through the cloud) (National Grid, n.d.).
- Singapore: Part of the uses that are mentioned in the SIEW is predictive maintenance, where the investment and research carried out in this use stands out, from which it is deduced that the desired state is one where predictive maintenance is mature in the network, so the gap is to achieve greater adoption of this use by adding improvements in its operation using new technologies such as,AI, Cloud Services, IoT,etc. (SIEW, n.d.).

6.6.1.3 **Barriers:**

Although predictive maintenance can be implemented today, it is emphasized that to achieve the desired state it is necessary to have a greater adoption of technologies (and advances in them) that complement this use, such as the acquisition of data in real time, or the use of AI, which would improve the performance of predictive maintenance.

Investment in more complex systems is presented as a barrier considering that this use requires more computational resources compared to current maintenance systems. In addition, the application relies on historical data that may need to be built up and not necessarily available immediately.

6.6.2 *Forecasting and predictions*

6.6.2.1 **Opportunities**

As forecasting and prediction becomes mainstream in the energy sector better efficiency can be achieved.

6.6.2.2 **Breaches and goals**

The existing gaps are related to the fact that the implementation of these uses is not yet massive, even though it has a high degree of scope in several of the countries investigated.

- US: The uncertainty around wind and solar power forecasts is still viewed by the power industry as being quite high, and many barriers to forecast adoption by power system operators remain. In response, the U.S. Department of

Energy has sponsored, in partnership with the National Oceanic and Atmospheric Administration, public, private, and academic organizations, two projects to advance wind and solar power forecasts. Additionally, several utilities and grid operators have recognized the value of adopting variable generation forecasting and have taken great strides to enhance their usage of forecasting. In parallel, power system markets and operations are evolving to integrate greater amounts of variable generation. No specific target tied to this topic where found, but better forecasting in energy sector, especially of variable generation sources, provide substantial economic and reliability benefits, in practice and in theory (Orwig et al., 2015).

- South Korea: The Energy Master Plan (Ministry of Trade, 2014) is an overarching plan that covers all energy sectors and coordinates energy related plans from a macro perspective. The Plan aims to provide a mid- to long-term vision of energy policy and sets targets to be addressed. This plan addresses forecasting in two initiatives related to governance.
    1) Statistics collection and management: "Open and integrated systems" establish a system for cooperation on statistics and policy and conduct
    2) joint forecasting between energy suppliers and related organizations.
    3) Public database availability: "Demand outlook" use energy information service systems to provide timely and appropriate information for policy makers and energy consumers through a reliable energy forecasting system.
- Singapore: By 2017 forecasting solar power output in Singapore, especially over long-time horizons, was challenging due to the complexities of their local weather systems. To mitigate the effects of solar intermittency and keep the power supply stable, EMA's (Energy Market Authority) power system operator would need to know the solar PV power output ahead of time in order to take appropriate actions to balance the grid. The Solar Forecasting Grant Call was launched on 8 March 2017 by EMA together with MSS (Meteorological Service Singapore), and awarded 6.2 million SPD to a consortium led by the National University of Singapore (NUS). The consortium will look into improving the accuracy of solar photovoltaic (PV) output forecasts and grid management using techniques in weather prediction, remote sensing, machine learning and grid modelling, in a four-year project (Energy Market Authority Singapore, 2017).

6.6.2.3 **Barriers**

It is recognized that there are no external incentives for electrical system operators. In addition, it requires an infrastructure that is responsible for obtaining the relevant data and information from the system in which it operates, which also involves high costs. On the other hand, historical data may not be easy to obtain.

6.7 Smart city

This section includes the international analysis of all the uses related to Smart city, that is, those uses that integrate a vision of the urban area of the future where smart ICTs connect the important sectors of the city, generating more efficient processes and optimizing social well-being.

This class is very well complemented when several uses of the same class are integrated into its implementation. For example, if the implementation of any use of Smart City is accompanied by technologies such as Big Data, Machine Learning and IoT, the use of user information is allowed for various uses at the residential level at the same time (such as smart home management , waste management and energy management), in addition to uses not associated with the digitization of the energy sector. From the point of view of the industry, the incorporation of the indicated technologies makes it possible to improve the efficiency of production processes, in addition to streamlining administrative processes by incorporating the digitization of information. Consequently, the implementation of the uses of this class requires the collection of a large amount of information, in addition to its processing. For the same reason, the level of investment in infrastructure is high when you think about mass adoption. Along these lines, the need for security systems that attend to the data traded in each of the associated interactions is recognized, understanding that an attack in this sense is highly dangerous for public safety. Finally, this class of uses complements very well with other uses such as those associated with mobility, DER management, Process management and Data management.

On the other hand, each of the uses associated with Smart City must consider the sensation of security and comfort of the users. The foregoing is vital from the social point of view, considering that most initiatives at the international level are also promoted by government agencies, whose interests of the latter are expected to be aligned with social welfare. In this sense, there must be the support of state entities that support the transition from a city without management capacity to a smart city. Likewise, it is necessary to communicate the need from local governments, so that the population understands the benefits of these applications. For all this, the incorporation of pilot programs is presented as a good option, in order to study the effects of the implementation of these uses in the context of different nations/regions.

The uses associated with this class are: Smart lighting, Smart traffic, Smart home & building, Smart industry, Smart farm, Smart parking, Smart waste management, Smart fleet management, and Smart water.

6.7.1 *Smart Lighting*

6.7.1.1 Opportunities

From the social point of view, smart lighting brings improvements in road safety for the population. Regarding the use of energy, this application contributes in energy efficiency. In general, public lighting systems are generic so technical feasibility is high and replication in a given context based on international experience is possible.

Incorporating street lighting control systems remotely can be helpful in delivering responses to lighting needs based on weather conditions, as well as allowing for a more responsive and efficient maintenance regimen, as it has warning and detection capabilities. automated failures.

6.7.1.2 Breaches and goals

The gap study was carried out based on the experience of Sweden, Finland, and Singapore, who through different pilot projects and policies have implemented this use.

- Sweden: GrowSmarter was one of the three projects chosen to receive the support of the European Commission in the first call for "Smart cities and communities" within the framework of the Horizon 2020 funding stream. Among its lines of work, Smart street lighting stands out, which aims to implement the most successful technology (s) to control a city's lighting program in order to provide optimal lighting for residents while reducing energy use and emissions of CO2 (GrowSmarter, n.d.). 3 sub-measures were tested: Sensor-controlled LED lighting for pedestrian and bicycle lanes, Self-controlled LED street lighting with preset lighting schemes, and remote-controlled LED street lighting that can be remotely controlled; whose results after the evaluation of the first 12 months were between 14.4% and 46% of annual energy savings, with sub measure 1 the one with the best results. Among the lessons learned from this implementation it is mentioned that the reliability of the data is not always guaranteed, the importance of the feeling of safety on the part of pedestrians is emphasized, the maintenance of these smart street lights could become more challenging with evolving technologies, among others. Furthermore, regarding its possible replication, it is stated that public lighting is generic and the technical feasibility is very good, at least in European cities. This experience also shows that due to very low electricity prices in Sweden, solutions are not economically sustainable and have long payback times.
- Finland: In 2017, the first LuxTurrim5G pilot program was implemented in the city of Espoo, a project whose objective is to allow viable commercial opportunities for digital services for the smart city environment. The project included the technical development of the smart light poles with integrated 5G radio technology, different sensors and other devices, as well as modern urban planning and new digital services and business concepts related to security, navigation, smart lighting, climate monitoring, information exchange and publicity. The level of investment required means that the initiatives associated with this project are still specified in specific test projects, since not only the installation of streetlights must be considered, but also antennas, base stations, sensors and others are needed. However, the good results of the first pilot led the project to expand and become a 5G smart hub (Business Finland, 2017).

- Singapore: The Singapore Land Transport Authority (LTA) announced that it will intensify its efforts to convert all roads in the city-state to more energy-efficient lighting systems and sustainable systems by 2022. To this end, energy-efficient LEDs have been implemented in street lamps. since 2013 and it is planned to replace the public lighting system with a Remote Control and Monitoring System (RCMS), in order to be able to control street lights remotely in response to lighting needs according to weather conditions. The RCMS also enables a more responsive and efficient maintenance regimen, as it has automated fault detection and alert capabilities. On the other hand, the Government Technology Agency will take advantage of the smart lighting infrastructure to test the feasibility of implementing a shared network for low-bandwidth wireless sensors and interconnecting the streetlights, this as part of the Smart Nation initiative.

6.7.1.3 Barriers

A security system is necessary for the data of the intelligent lighting system, an attack in that sense is highly dangerous for public safety, the reliability of the data is not always guaranteed. The implementation of this use must emphasize that the lighting management must be in accordance with the feeling of safety and comfort of pedestrians or users.

It requires the support of citizens and state entities that give value to its implementation and generate public policies. The use of pilot projects makes it possible to determine the appropriate system for the implementation of intelligent public lighting according to the case study.

6.7.2 *Smart Traffic*

6.7.2.1 Opportunities

Smart traffic contributes to the reduction of emissions thanks to the reduction it implies in travel times, on the other hand, this also means an increase in the well-being of people due to the better functioning of the traffic.

6.7.2.2 Breaches and goals

This use is part of the goals associated with "smart mobility" in multiple countries, whose goals such as reducing bottlenecks or reducing emissions still imply a gap between the desired state and the current one. Below are the cases of UK, Singapore and Finland.

- UK: In England there is the National Traffic Control Center (NTCC), whose objectives promote this use. To achieve the desired state of this use, it is necessary to implement VANETs and 5G, technologies that are currently under development by the department for transportation (Department for Transport UK, 2017).
- Singapore has the "smart mobility 2030" program (Kian Keong & Ong, 2015), whose objectives are complemented by this use, since within its objectives is the reduction of traffic congestion and mitigating the impact of accidents on the roads, the gap to achieve this is the renewal of both fleets and infrastructure, allowing the use of new technologies to implement intelligent traffic.
- In Finland, vehicular traffic is managed by Intelligent Traffic Management Finland (TMF, n.d.), and there is also the "Smart Mobility Finland" program (Business Finland, n.d.), which seeks to achieve disruptive mobility services and traffic systems (intelligent traffic). It was mentioned that one of the gaps to meet this objective is the participation of international actors to build new innovation ecosystems in this area.

6.7.2.3 Barriers

A greater implementation of VANETs and 5G stations. In addition to the renewal of fleets so that more vehicles can participate.

On the other hand, the infrastructure that must be implemented for this use, and the use of vehicular networks can slow down their incorporation, since not all users will have vehicles capable of interacting with this technology (although they would benefit once the system is implemented).

6.7.3 *Smart Home & Smart Building*

6.7.3.1 **Opportunities**

The increase in the number of smart devices and advances in data science are the main opportunities for this use. The new products and services offered by private companies give it more utility and promote the use of smart homes. Advances in Big Data, Machine Learning and IoT also provide opportunities for this use, thanks to the possibility of using user information for other uses such as smart waste management, or energy management, in addition to uses that are not associated with the digitization of the energy sector. The use of these technologies brings with it a boost in innovation for the industry and an increase in the security of supply thanks to the greater control of the network.

6.7.3.2 **Breaches and goals**

One recognized target at an international level is to develop broad standards in the smart home and building industries, in order to promote higher adoption and enable new applications. Efforts are usually carried out by international taskforces within private-funded initiatives, such as the Zigbee Alliance[11] and Smart Electric Power Alliance[12].

- US: Of about 117 million U.S. homes in 2016, about 17 million had some type of smart home device. By 2020, 40 million smart thermostats are expected in U.S. homes with 50 million smart light bulbs, and 12 million smart water leak detectors. Sales of connected home technologies grew almost 1500% from 2012 to 2017, and explosive growth is slated to continue as competition increases and vendors expand how devices interact with other businesses and services (US Department of Energy, 2018). No specific target was found for Smart Home.
- UK: Smart home devices are becoming ever more present in UK households. Penetration has reached almost a quarter (23%) with smart speakers (11%) leading the way (TechUK, 2019). A PWC survey indicated that £10.8 billion will be spent on smart home devices in 2019, in the UK (YouGov, 2018). The top drivers for adoption are Confidence, interoperability and comfort, and the barriers are Cost, Knowledge and Privacy. The principal interfaces to control the smart energy devices are the smartphone and home hub or speaker.
- South Korea: The South Korea smart home market is anticipated to exceed US$ 6 Billion by 2025. In the country, household penetration for smart home applications was estimated at 20.6% in 2018. Smart Appliances captured maximum share of the South Korea smart home market. Smart Home - Driving Factors are: 1) Policies & Initiatives to Promote Smart Homes. 2) IoT Drives Smart Home Market. 3) Cost Savings Due to The Adoption of Energy Conservation Systems. 4) Increasing Awareness & Importance of Home Monitoring from Remote Locations. 5) Development of Connected Innovative Products (PR Newswire, 2019).

6.7.3.3 **Barriers**

The use of user information is an important part of smart home & buildings; this brings with it a barrier on the part of the users themselves against the insecurity of the use given to their data. The "sovereignty of information" is the main barrier, which may, in addition to its social component, have a regulatory axis to set the limits that this use will have in terms of data access for its users.

The high cost of the technology necessary for smart home & building is another barrier to consider, however, the rapid technological advances in this area could make the massification of this use viable in the medium term. On the other hand, the necessary cybersecurity also limits this use, safeguarding user information is a complex challenge if this use becomes widespread.

[11] https://www.connectedhomeip.com/
[12] https://sepapower.org/about/

In terms of connectivity, there are several wireless technologies enabling the deployment of Smart Home and Smart Building applications. Among them are the ZigBee, Z-Wave, Bluetooth, and WiFi technologies. Although each of these technologies relies on standard definitions (with some being proprietary technologies, such as Z-Wave), there is no single technology established as “the standard” for the Smart Home and Smart Building use case. Since several devices in the same local area may have radios with different wireless technologies, the lack of interoperability becomes a barrier to their rapid deployment in Smart Home scenarios. A higher-layer protocol such IP (IPv6 to be more precise) could help integrating different technologies—thus different devices—in a single solution. However, most of the short-range/low-cost wireless technologies suggested for Smart Home scenarios do not transport IP packets. Nonetheless, it is expected that in the short term, the lack of IP support will be solved by international standards defined by the Internet Engineering Task Force (IETF), which is finalizing the definition of IP support and related protocols in working groups such as 6LoWPAN and 6lo.

6.7.4 Smart industry

6.7.4.1 Opportunities

Improves the efficiency of production processes. Streamlines administrative processes by incorporating digitization of information.

6.7.4.2 Breaches and goals

It requires state support for those SMEs that cannot make the transition to smart industry, considering their economic capacity and knowledge on the subject. Likewise, it is necessary to communicate the need from local governments, so that the population understands the benefits of this application. The incorporation of pilot programs of intelligent industries is presented as an option, either for the digitization of their data or for the automation of processes. This is exposed in the specific analysis carried out in South Korea, Japan, and France, shown below.

- South Korea: The Korean New Deal proposes that by 2025 there will be 15 smart industrial complexes, which will be simulation centers to test manufacturing processes and adopt remote monitoring systems against the emissions of toxic chemicals, using AI and drones. On the other hand, its National Artificial Intelligence Strategy aims to build 100 smart factories by 2022, and 2000 by 2030, which are based on AI, which increases productivity and reduces waste through process optimization. by analyzing digital data using AI.
- Japan: Japan aims to achieve "Society 5.0" in the future by fully utilizing technological innovation, including IoT, AI, and Big Data derived from the fourth industrial revolution. In this regard, Japan has announced Connected Industries (Ministry of Economy, n.d.), which aims to generate the conceptual framework in which industries will create added value, not only increasing efficiency and optimizing the manufacturing process, but also connecting the strengths of Japan's manufacturing industry.
- France: The Industry of the Future initiative (European Commission, 2017) is transversal and aims to modernize the entire French industry. For this, more than 500 trained experts provided support to more than 7,400 SMEs throughout France between 2016 and 2017. On the other hand, industrial companies have invested around 25,000 million euros a year in R&D since 2016, which represents two thirds of the total R&D expenses contracted by French companies, where the automotive sector has become the engine of innovation, taking 13% of the total. Added to this is the government's initiative to incorporate a tax relief for investment in robotics or information technology for SMEs, up to 40% of the total investment, the support of the regions for the digital transformation of 10,000 SMEs by 2022 and the creation of a regional acceleration platform for industrial technologies, designed to disseminate knowledge and good practices in local ecosystems.

6.7.4.3 Barriers

An important barrier to mention is the transition process from a non-digital industry, with non-automated processes and without trained personnel, to a smart industry. This transition implies important investments in equipment and training, as well as the accompaniment of an external agent that allows support in the change process. Its high investment cost could be beaten through government intervention by incorporating a tax relief for investment in robotics or information technology for SMEs. The creation of regulatory frameworks around the incorporation of this use should also be considered. All of the above accompanied by new regulatory approaches.

Another aspect to consider is the lack of personnel trained in data analysis, the intelligent industry brings with it large amounts of data associated with the manufacturing process, distribution, etc. that need to be converted into useful information to be able to make decisions. Many industries do not have capabilities in this line and therefore it is a barrier for them to make the transition. Finally, cybersecurity also needs to be considered, as the data might be associated with sensitive information of the industrial processes.

6.7.5 Smart Farm

6.7.5.1 Opportunities

The climate crisis gives value to the optimization of water use, and this use can be complemented by smart water, giving smart farming an opportunity to enter the market. On the other hand, droughts in various sectors of the world have affected the agricultural market, taking this into consideration, smart farming appears as a powerful tool to face this problem, thanks to the support it provides to farmers, further enhanced by the Big Data and even the IoT. The use of smart farms also reduces the costs of electricity services thanks to the efficient use of energy and increases social welfare thanks to the improvement in the production of farmers.

6.7.5.2 Breaches and goals

The reality of this use in the international arena is analyzed below in the cases of South Korea, UK and China:

- South Korea: The Korean New Deal proposes that by 2025 there will be 15 smart industrial complexes (including smart farms for lease), which will be simulation centers to test manufacturing processes and adopt remote monitoring systems against the emissions of toxic chemicals, using AI and drones (Korea Times, 2019). On the other hand, its National Artificial Intelligence Strategy aims to build 100 smart factories by 2022, and 2000 by 2030, which are based on AI, which increases productivity and reduces waste through process optimization, by analyzing digital data using AI (The goverment of the Republic of Korea, 2019).
- UK: Smart Farm is part of the government's "Industrial Strategy" which, among other objectives, seeks to boost agricultural productivity through new technologies. For smart farming, the gap between current and desired state is the adoption of artificial intelligence and automation in the agricultural industry (FarmingUK News, 2018).
- China: Smart Farming is currently being used in China, taking advantage of advances in big data and even 5G. The use of 5G technologies is an innovation and once a breakthrough, because although they have already started to configure 5G stations for smart cultivation, a greater adoption of these stations is expected in the future to optimize production (CGTN, 2019).

6.7.5.3 Barriers

A significant barrier in this use is the constant need to have access to the Internet, so its use in rural communities, which is where this use would be most applied, is very complex given its limited access to the network. Linked to internet access, the lack of connectivity in the areas where it would be applied implies a scarce familiarization with new technologies, so the implementation of smart farming could be affected by lack of knowledge or interest on the part of potential users, also considering that an important part of them are not "digital natives". In addition, a social / cultural barrier must be considered. Since the intervention of highly manual processes with new technologies is not easy to execute, there is a barrier to entry imposed by the farmers themselves who want to maintain the status-quo (even if the connectivity part is resolved)

6.7.6 Smart Parking

6.7.6.1 Opportunities

The development of this use is closely related to the IoT, the development of MANETs in the context of the smart city, and vehicular networks. Those technologies provide tools that facilitate the implementation of smart parking, which could also be implemented jointly with autonomous vehicles. There is a great opportunity for increasing the well-being of the population, as well as promoting innovation, by reducing both the time spent looking for parking and the time that a vehicle is parked.

6.7.6.2 Breaches and goals

As Smart Parking is a wide concept, there are many ways of implement smart parking schemes to close the gap between non-optimizing at all (flat rates and unused parking space) and a smarter way of parking. To identify some current smart parking implementation, three cities in the US where revised.

- San Francisco: Demand-Responsive Parking Pricing[13]. Through smarter pricing for parking, the city helps to achieve the right level of parking availability by periodically adjusting meter and garage to match demand. Known as "demand-responsive pricing," this encourages people to park in underutilized blocks and garages, helping to open up spaces in busy areas and at busy times. The SFMTA Board of Directors adopted the Demand-Responsive Pricing Program on December 5, 2017.
- Santa Monica: The City of Santa Monica[14] uses current technology and real-time information to keep cars moving on major boulevards and limit the impact of regional traffic on local streets. This includes a comprehensive street wayfinding system, including signs directing motorists to off-street parking and displaying real time parking availability at many public parking facilities including parking meters. Parking rates reflect the value of parking and are set to ensure that spaces are available when needed.
- St Paul (Minnesota): The city put out an app[15] to help people find a spot. The app is free and features maps of where to find ramps and meters. It also has parking prices. You can even reserve a parking sport for some ramps. The city's web app also links up with another app so you can pay for parking with your smart phone.

6.7.6.3 Barriers

Some regulatory reforms may be needed in order to implement smart parking in populated cities with parking regulation that do not conceive dynamically assigned prices nor spaces. From a technological perspective, the spatial-temporal monitoring of parking space and traffic and feeding of real-time information to end users may require investment in infrastructure from business or public entities with less, or non, expertise in ICT.

6.7.7 *Smart Waste Management*

6.7.7.1 Opportunities

The need to reduce emissions due to the climate crisis and the considerable technological advances in smart sensors are an opportunity for the implementation of this use. The arrival of smart cities and the IoT complement this use, facilitating its implementation thanks to its advances in ICTs. This use brings with it an improvement in the well-being of people thanks to the efficient management of waste (visual and odor pollution).

6.7.7.2 Breaches and goals

The general gaps recognized in this use are largely associated with those related to "Emissions Monitoring". In any case, the experience found in Denmark is exposed, this being the only international experience where Smart Waste is explicitly implemented as a concept.

[13] https://www.sfmta.com/demand-responsive-parking-pricing
[14] https://www.smgov.net/Departments/PCD/Transportation/Motorists-Parking/
[15] https://www.stpaul.gov/parking-saint-paul

- Denmark: The Waste Management Plan (WMP) is a framework for actions related to waste aimed at citizens, businesses and the municipality of Kolding (Smart Waste Interreg Europe, n.d.). This plan has a focus on zero waste and circular economy, and involves the refurbishment of commercial buildings, educating the population on the subject, among others. Its goal is to achieve a high level of recycling: from 25% in 2013 to 50% by 2022. To achieve environmental objectives, imposed at the national or regional level, the need to incorporate the Internet of Things (IoT) is considered, to carry out waste collection and avoid littering at collection sites.

6.7.7.3 **Barriers**

Considering the purpose of this use (to reduce emissions), once implemented it is also required that society take advantage of the tool provided, for this the population must be made aware of the importance of emissions, otherwise the scope of this use is very limited. On the other hand, the investment cost involved in smart waste management could discourage private companies from implementing this use, which could be resolved through incentives and/or regulations. It requires an awareness program regarding the problem of emissions and the importance of its monitoring and incorporation of mitigation measures.

Another barrier is the high computational cost that its implementation would have in a massive way, in addition to the large number of sensors and actuators that must be managed for this use, data management requiring the addition of the emissions within the information managed by AMIs.

6.7.8 *Smart Fleet Management*

6.7.8.1 **Opportunities**

Favorable in the face of the climate crisis through the reduction of fuel consumption. In the economic sphere, a reduction in operating costs is observed, due to the reduction in fuel consumption, and maintenance. From a social point of view, smart fleet management offers direct benefits to users, reducing traffic congestion implies an optimization of the population's time and, consequently, an increase in people's quality of life. In environmental terms, this application has relevant opportunities. The implementation of optimal fleet management accompanied by the incorporation of electric vehicles (EVs) and vehicle-to-grid (V2G), directly affects the energy consumption necessary for its operation, as well as allows the use of traffic information for a better use of the energy injected or consumed by vehicles.

6.7.8.2 **Breaches and goals**

The gaps in this use are associated with the ICTs linked to use, to meet the goals at an international level, the cases of Finland, Singapore and UK are exposed for this use:

- Finland: This use is part of the "Smart Mobility" program (Business Finland, n.d.), which seeks mobility solutions based on IoT, AI and 5G. The gap in this use is linked to these technological advances, since in order to fulfill the objectives of this program, Finnish companies are required to participate in the development of software to achieve new solutions and innovative technologies.
- Singapore: Within the "Smart Mobility 2030" program (Kian Keong & Ong, 2015), the Intelligent Fleet Management System is considered, whose goal is to integrate and simplify resource management, together with improving productivity and quality of service. The gap in achieving these improvements is the integration of information from different bus operators, as well as greater integration of sensors and location-based services.
- UK: As in smart traffic, this use is for the objectives of the NTCC, whose gap between the current and desired state is the implementation of VANETs and 5G stations (Department for Transport UK, 2017).

6.7.8.3 **Barriers**

In technical terms, its implementation considers an important penetration of sensors, which, together with communication systems and algorithms for predicting traffic congestion, efficiently manage the vehicle fleet. On the other hand, the sovereignty of the information processed must be determined and who or who would have access to said information must be defined.

6.8 Other uses

In this section, an analysis is made of the uses that, given their definition, do not belong to the previously reviewed classes, but that must also be considered for the digitization of the energy sector.

Many of the uses belonging to this class are favored by others as they are a complement to them, for example, Energy Management, ancillary services and Operation (monitoring / control / reporting) are useful for DSM / DR (or Distributed Generation) and vice versa. Linked to this, the gaps mainly point to the implementation of technologies that allow the maturity of these uses, such as increasing connectivity for teleworking. On the other hand, there are barriers associated with the new information that is needed and that is generated; the handling of user data through EMS, or the confidential information of companies that is handled in teleworking must now also be considered in terms of cybersecurity, involving regulatory and technological barriers.

The aforementioned is a brief synthesis of the analysis by uses of this class, below a detailed analysis of each use is made separately, where the aforementioned is also deepened.

6.8.1 Market management & operation

6.8.1.1 Opportunities

Since market management & operation considers these wholesale markets as services and DR, the opportunities associated with uses are also for market management & operation, the increase in distributed resources added to this use will generate new markets associated with complementary services and DR, and the need for managing their participation is an opportunity to promote innovation and decrease the price of energy. This use also generates a positive impact on supply security through the complementary services market.

6.8.1.2 Breaches and goals

The amount of data to be handled with this technology is not negligible, although this may be theoretically and regulatory feasible, it is necessary to have the necessary infrastructure to obtain and deliver the information in adequate times, which could generate problems in countries where electricity grid doesn't have the equipment for this. In addition, the regulatory framework that determines the way in which the information will be managed, their sovereignty and who would have access to them should be considered.

In addition, there is a need for legislators and regulators to determine strategies to remove barriers and facilitate new markets, allow new forms of transactions, and empower consumers. This as a quick response to change.

The specific gap analysis was carried out on the experience of the European Union and the United States.

- EU: The report "Digitization of the energy sector" prepared by SETIS for the European Commission (*JRC Publications Repository: SETIS Magazine: Digitalisation of the Energy Sector*, n.d.), shows the benefits of the new opportunities resulting from the incorporation of ICT in the energy sector, which highlights the operation, planning and management of assets of the most efficient network through smart grids, as well as the creation of new markets. The digitization of the energy sector shows benefits regarding access to information, making available to regulators and monitors the data collected and managed by market facilitators. For example: the IDE4L project developed digital tools that allow the flexible demand to be integrated into the market, considering the technical limitations of the network in the market operation. However, the same document recognizes as one of the main challenges the need for investment in cybersecurity, to guarantee a safe transition from the EU to a decarbonized, decentralized and digitized system. That is why the EU developed a cyber security strategy (European Commission, 2013) in order to establish the EU approach to prevent and better respond to cyber attacks and interruptions, while DG CNECT and the Directorate General for Energy (DG ENER) are developing a comprehensive strategy on how to strengthen the operation of the Network and Information Systems Security Directive (NIS Directive) in the energy sector. The need to reduce the cultural gap between the Operations and Information Technology divisions is also identified. In addition, it is determined that companies that provide energy services must adopt a holistic approach that incorporates key phases of cybersecurity: prepare and prevent, detect and respond, recover and share.

- US: The document "New Policy for an Era of Energy Digitization: Energy" produced by the non-profit organization EC-MAP (EC-MAP, 2018), mentions the benefits of incorporating digital technologies in energy systems, promoting the change from decentralization, connectivity and automation. This document also exposes the need for legislators and regulators to determine strategies to remove barriers to facilitate new markets, enable new forms of transactions, and empower consumers. It also refers to the inability of governments to act quickly in the face of changes. Among the recognized barriers to the integration of innovation and efficiency in the market are: low or no market incentive for companies to incorporate new technologies and business models or prioritize customer choice, competition at the wholesale level varies from state to state and regions, there are also no incentives or requirements for companies to share electricity data, there are high entry barriers for participation in the wholesale and retail market of DER and third-party energy service providers.

6.8.1.3 **Barriers**

Considering that the DR and ancillary services market is not yet mature and that they will have a significant impact on the electricity market, a barrier to this use is regulatory obstacles. In order to participate in the market, the necessary laws and regulations must be established, which could slow down their implementation.

It requires a cybersecurity system to accompany it in order to prevent and better respond to possible attacks and interruptions, this through governmental strategies and internal company policies.

Among the recognized barriers are: low or no market incentive for companies to incorporate new technologies and business models or prioritize customer choice, competition at the wholesale level varies depending on the national context, in general there are no incentives or requirements for companies to share electricity data, there are high barriers to entry for wholesale and retail market share from DER and third-party energy service providers.

6.8.2 *Ancillary services*

6.8.2.1 **Opportunities**

The integration of distributed resources requires ancillary services, considering the variability of renewable energies, in addition to the versatility provided by storage and EVs, the participation of ancillary services (and their market) becomes more relevant, since it reduces the time without supply, and leads to new business models.

6.8.2.2 **Breaches and goals**

The digitization of the energy network brings with it multiple new ancillary services, below are the gaps in this use in the USA, China and UK cases:

- USA: The improvements in this use are linked to the modernization of the electrical network. For this use, the gap in user participation stands out, which for the network to be modernized must be more relevant, on the other hand it is highlighted that it must respond more quickly to power issues and expand the data acquisition system to reach the desired state (US DOE, n.d.).
- China: In the Chinese case, the modernization of the network aims to facilitate the incorporation of NCRE. For this purpose, the ancillary services become relevant thanks to the robustness they give to the network. In "Regulatory pathways for smart grid development in China" (Brunekreeft, n.d.) gaps are mentioned, being the one that best fits to this use the development of technologies for updating the distribution network and a greater insertion of energy storage (as an ancillary service).
- UK: This use is an important part of the modernization of the network in the UK, however there are still gaps to reach the desired state, in "Smart Grid Vision and Routemap" (*Smart Grid Vision and Routemap Smart Grid Forum*, 2014) it is mentioned that must be established a framework of standards that form the basis of an intelligent network for all

residentials homes, industrial warehouses and associated buildings; within this framework of regulations this use should be considered.

6.8.2.3 Barriers

The counterpart of the inclusion of distributed resources is the high complexity that they add to the ancillary services, the need to have generation forecast information or the response on demand suggest that the ancillary services should be able to work in conjunction with these applications, requiring an update in the existing infrastructure to increase its computational capacity for its correct implementation in the market.

Regulatory changes should be considered, which make the entry of new agents more flexible into the complementary services market and allow an active participation of the agents involved, responding to the needs of the system. Added to the above is the need to correctly define the associated payments, so that there is a correct remuneration associated with the provision of these services.

6.8.3 *Energy management*

6.8.3.1 Opportunities

The IoT and the growing number of products and services offered by private companies associated with smart homes (Amazon, Apple, Microsoft, etc.) bring opportunities for the energy management system, providing it with a greater number of devices to control and extract information, allowing greater savings in energy consumption. On the other hand, electrification of heat and applications such as smart lighting and smart heating complement energy management, giving you more opportunities. These opportunities facilitate the entry of this use, which in turn implies a promotion of innovation and reduces the price of energy.

6.8.3.2 Breaches and goals

The adoption of an EMS by end users is lagging behind expectations and it faces two major challenges. The first challenge is the “background technology”. From the user’s point of view at the moment, the use of electricity is unreflective and very easy. Introduction of a HEMS will change this situation. If users are to implement such a technology in their everyday lives, the technology must compensate them for the cost of additional time and attention. That leads us to the second challenge: the challenge of financial remuneration, reduction in energy bills needs to meet users' expectations (Kowalski & Matusiak, 2019). This use is highly related to “Smart Home and Building”.

- US: Though connected home technologies are increasing in availability and popularity, as it is described in the “Smart Home and Building” use section, none are yet fully “plug and play” to easily enable energy savings or load shifting. Integrating devices such as Amazon Echo and Google Home into home energy systems can be cumbersome and often requires the purchase of additional appliances to fully realize potential cost savings. Nevertheless, the technology maturity (e.g., user interface, controls) is beginning to come together with declining costs to enable future widespread use. Business owners are also beginning to adopt building energy management systems that allow more precise control and automatic settings to drive down energy use and costs. Since 2011, the market for building energy management systems has grown from $737 million to more than $1 billion and is expected to grow faster—more than ten-fold—in the next decade.
- South Korea: The revenue in the South Korean Smart Home Energy Management segment reached US$ 170 Million in 2018. Energy management is one of the key factors driving the Smart Home industry.

6.8.3.3 Barriers

Energy management requires the use of user data to function properly, this can generate a social barrier for this use. Recent privacy problems by companies that are leaders in smart home services / products have generated distrust when handling information to third parties by users. This affects this use as users could be subtracted from energy management due to suspicions about the use that could be given to their information.

6.8.4 *Operation (monitoring/control/reporting)*

6.8.4.1 **Opportunities**

The increase in distributed resources in the network gives coherence and support to the inclusion of these technologies, in addition to ad-hoc networks and the IoT can facilitate the use of these technologies. Advances in predictive maintenance in conjunction with this use will allow significant cost reductions, and reduction of times without energy supply, and increased supply security.

6.8.4.2 **Breaches and goals**

The scope of this use requires accessibility to the information, the high connectivity necessary to have total control over the network can leave out a significant portion of the load, which may result in incomplete monitoring / analysis, considering that soon the distributed resources will increase considerably and it is expected that their connectivity grow at the same rate.

- UK: The Catapult report sponsored by the Department for Business, Energy & Industrial Strategy, Ofgem and Innovate UK, provides a series of recommendations on how to harness the power of data in the British energy system (Catapult Energy Systems, 2019). The document recognizes the operational benefits of the digitization of the energy system, referring to solutions that combine strategic monitoring with data science, analysis and modeling to maximize the value of the investment, instead of relying solely on the massive deployment of equipment. The report repeatedly recommends that in addition to regulatory interventions there should be long-term data strategies on the part of organizations.
- US: To stay competitive in electric-power generation, gas- and coal-powered plants need to improve fuel efficiency and performance. A digital-enabled operational transformation allows them to do so. In the United States, 1,800 gas plants and 300 coal plants provided three-quarters of generation capacity in 2017 (720 gigawatts (GW), approximately 460 GW of gas and 260 GW of coal, out of approximately 1,100 GW of net summer capacity). McKinsey forecasts indicate that the United States will still use approximately 725 GW of fossil-based generation: approximately 550 GW of gas and 175 GW of coal in 2030. To achieve the requisite step change in performance, fossil-fuel plants should embark on a transformation that combines digitization and advanced analytics with classic lean operations (Guzman et al., 2019).
- EU: In the "Cyber Physical System for the Energy Transition" (ENTSO-E, 2019) ENTSO-E's document "System operation" is one of the five layers in the digital grid concept. In the document it is said that digitalization will enable the development of a new set of tools in control rooms that can offer the operator a whole new level of hyper-vision and automation, from two days ahead up to real time, to face a context of an increasing number of uncertainties and interlinkages. The policy objectives highlighted in this document that analyze more than 100 projects in the ENTSO-S domain are: 1) At least 40% cuts in greenhouse gas emissions (from 1990 levels), 2) A 32% share for renewable energy, and 3) 32.5% improvement in energy efficiency.
  The same document mentions the “2030 climate and energy framework”, that it helps drive progress towards a low-car-bon economy and build an energy system that: 1) Ensures affordable energy for all consumers, 2) increases the security of the EU’s energy supplies, 3) reduces dependence on energy imports and increases the RES (renewable energy sources) integration, 4) creates new opportunities for growth and jobs. Of all the projects covered in the document, 56 projects are deployed for system operation purposes. This emphasizes the importance of this layer and how it functions as a bridge between the physical layer and the market layer. Ultimately, system operation is the backbone for the further development of the Digital Grid.

6.8.4.3 **Barriers**

The edge of "reports" could generate conflicts in users if they include information from users who use distributed resources (EV, or DSM), however this is not typical of the report but of the use of private information itself, which generates barriers associated with cybersecurity and protection of user data. No barriers are identified other than the delay in its implementation due to the legislative processes or the creation of necessary regulations in each country.

6.8.5 *Teleworking*

6.8.5.1 **Opportunities**

An obvious opportunity for the adoption of teleworking is the reduction of GHG emissions due to the decrease in the need to mobilize employees to their jobs. This decrease in relocation also implies a reduction in expenses and time for employees, while for employers, office maintenance costs are reduced.

Further, this modality entails greater time flexibility for employees, to take advantage of an organization adapted to the personal needs of each person.

6.8.5.2 **Breaches and goals**

The growth of teleworking due to COVID-19 has brought new goals regarding this use. Below are the cases of three countries where gaps associated with this use are made explicit (South Korea, USA and Singapore).

- South Korea: With the Korean New Deal, up to 40 percent of the work is expected to be done remotely.
- USA: Cybersecurity and infrastructure security agency (CISA[16]) hopes to increase cybersecurity in telecommuting through improvements in related infrastructure.
- Singapore: The Singapore Computer Emergency Response Team[17],[18] seeks to make teleworking safer, which is why it promotes and is expected to implement telework policies at the corporate level.

6.8.5.3 **Barriers**

The separation of workspaces and "personal life space" is under attack, so employers must guarantee compliance with working hours. On the other hand, some tasks are not possible to carry out in teleworking mode, such as production processes, most medical tasks, among others. Also, some sectors even faced with the need have not been able to adapt to this modality, mainly due to the prior unavailability of digital data, lack of technologies, and employee training. In addition, it should be considered that it can also generate an impact on employees because it could damage the feeling of belonging and bond with the work team.

[16] https://www.cisa.gov/telework
[17] https://www.csa.gov.sg/singcert/advisories/ad-2020-001
[18] https://www.csa.gov.sg/singcert/publications/working-safely-from-home

7 Policies that promote digitization at the international level

In addition to the details of countries and their policies mentioned before, this section presents a detailed analysis of successful policies for three specific countries.

7.1 *United Kingdom: "Road to Zero"*

The Road to Zero - *Next steps towards cleaner road transport and delivering our Industrial Strategy* (Department for Transport UK, 2018), is a national policy published in 2018 with long term ambitions to put the UK at the forefront of the design and manufacturing of zero emission vehicles, and for all new cars and vans to be effectively zero emission by 2040, and almost every car by 2050 (GOV.UK, 2018). Those are important targets considering the current state of UK's vehicle fleet and the impact that transport had on UK GHG emission, when the policy was design. Figure 19 and Figure 20 shows, respectively, the ratio of fossil fuel vehicles in UK by 2017 and the tear down of the country emissions in 2016.

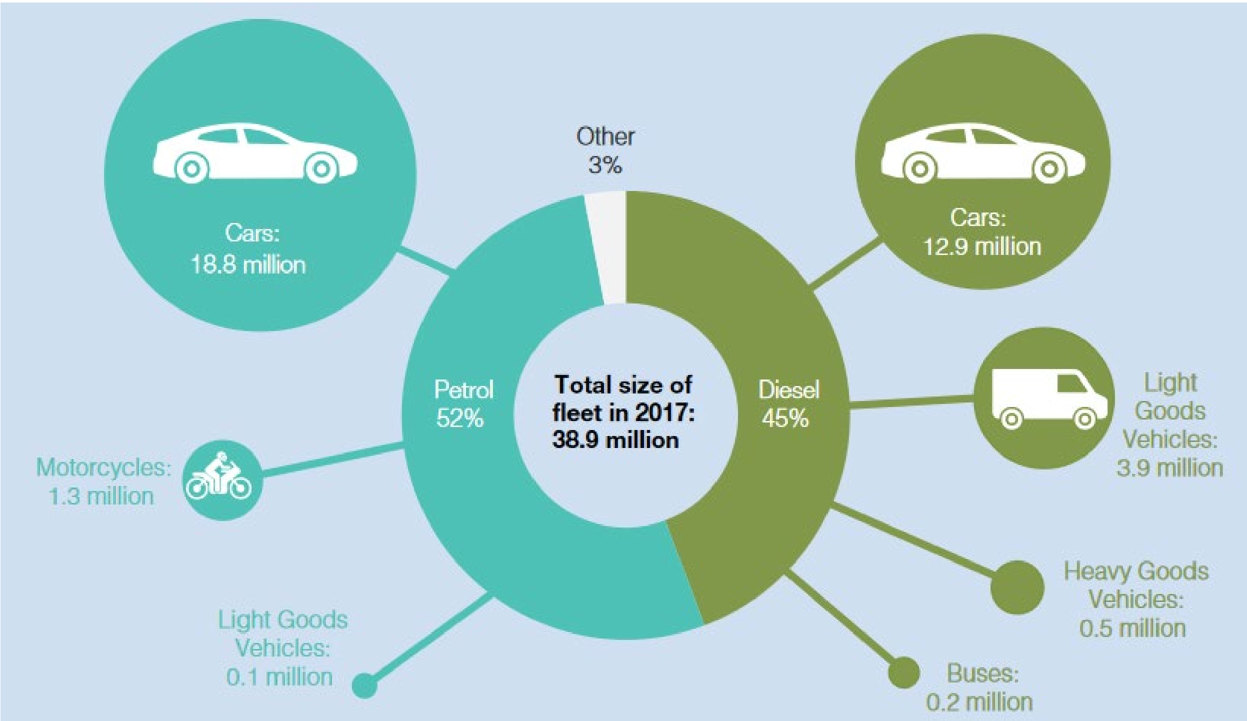

Figure 19: The vast majority of the vehicles currently on UK roads are petrol or diesel fueled
Source: DfT, Vehicle Licensing Statistics 2017

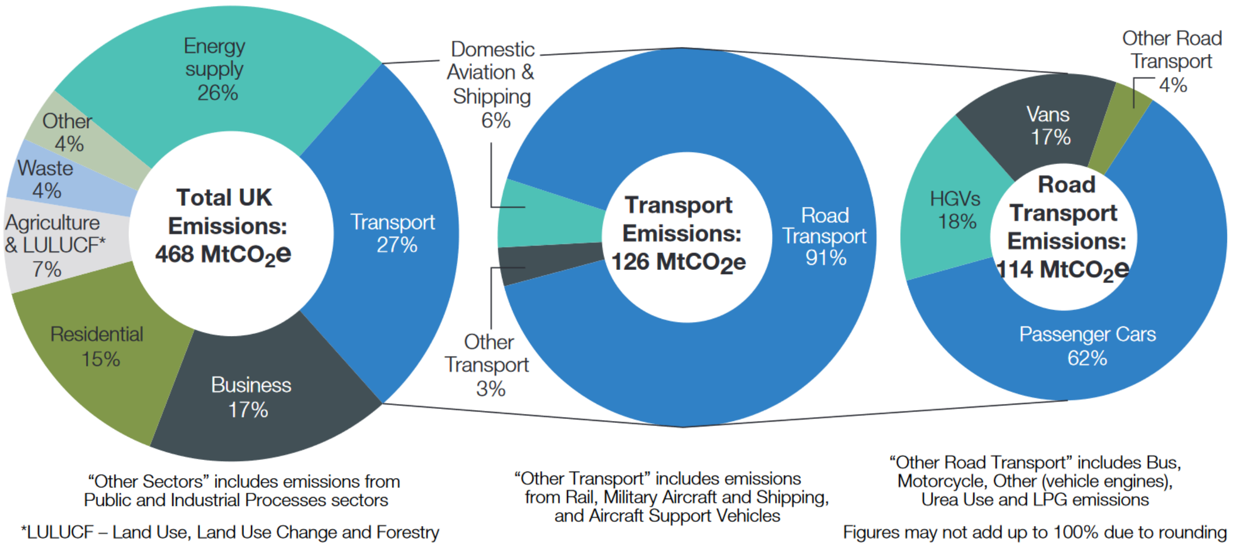

Figure 20: In 2016, road transport accounted for 91% of UK greenhouse gas emissions from transport

Expectations are for the transition to be industry and consumer led, supported in the coming years by the measures set out in the strategy and review of the progress will be done in 2025. Against a rapidly evolving international context, the vision of the government is to maintain the UK's leadership position and meet their ambitions, and to consider what interventions would be required if not enough progress is being made.

In the policy document, 46 courses of action (funding, taxation changes, taskforces, competitions, etc.) are listed supporting 6 general objectives:

- Reduce emission from vehicles already on roads (4 actions)
- Promote the uptake of cleaner new vehicles (10 actions)
- Reduce emissions from heavy good vehicles and road freight (4 actions)
- Put the UK at the forefront of the design and manufacturing of zero emission vehicles (7 actions)
- Support the development of one of the best electric vehicle infrastructure networks in the world (17 actions)
- Support of local actions (4 actions)

The Strategy is technology neutral and does not speculate on which technologies might help to deliver the government's 2040 mission. The government has no plan to ban any particular technology, like hybrid vehicles, as part of this strategy.

Carried out by the department of transport, "The Road to Zero" is part of UK's Industrial strategy (HM Government UK, 2017), a government national policy that aim to create an economy that boosts productivity and earning power throughout the UK, upon five foundations: Ideas, People, Infrastructure, Business environment, and places. The Industrial Strategy identifies four grand challenges: Growing the AI & Data-Driven economy, Clean growth, The Future of Mobility, and the Ageing of Society. The Road to zero strategy focuses on The Future of Mobility.

7.1.1 *The Future of Mobility Challenge*

The challenge states that the move to zero emission road transport will not be the only shift in the way goods, people and services are moved, and that significant investments are being made in the automation of road vehicles, while new business models and new mobility services are challenging the general assumptions about travel. The way people travel and who owns vehicles in the coming years will affect the trajectory of ultra-low emission vehicle uptake, the infrastructure these vehicles will need and emissions from conventional vehicles. Relevant trends include:

- **Connectivity and automation**, vehicles where some or all the driving task is automated may result in smoother more efficient drives. In addition, vehicles which communicate with each other and with infrastructure could improve traffic flow and therefore reduce emissions.
- **New Business Models**, fewer young people are learning to drive and buying cars. Digitally enabled, on-demand and shared transport services are already changing how people consume mobility in the UK. This could signal a shift to fewer vehicles on the road with higher utilization rates. Some analysts forecast dramatic declines in individual car ownership in the coming decades.
- **Changing travel Demand**, people increasingly work from home and fewer people commute Monday to Friday. This means the patterns of road vehicle use and levels of congestion in urban areas are changing

UK government had launched the Future of Mobility Grand Challenge to recognize the magnitude of changes such as these on the transport system and would launch a call for evidence on the Future of Mobility shortly ahead of publishing a strategy later in 2018 (The Road to Zero).

7.1.2 *Funding initiatives*

Important funding is highlighted in this policy, from the list of actions announced, the ones that commit funding, of some sort, are:

- Making the biggest increase in public investment in R&D in their history (towards a target for total R&D investment of 2.4% of GDP by 2027) and increasing the rate of R&D tax credit to 12%
- Provide £246 million to research next generation battery technology through the Faraday Battery Challenge
- Launching a £400 million Charging Infrastructure Investment Fund to help accelerate charging infrastructure deployment.
- Increasing the grant level of the Workplace Charging Scheme from £300 per socket to 75% of the purchase and installation costs of a charge point capped at a maximum of £500 per socket
- Investing £4.5 million in the On-street Residential Charge point Scheme until 2020
- Launching the process for a R&D program of up to £40 million by summer 2018 to develop and trial innovative, low cost wireless charging and public on-street charging solutions that can be deployed across entire residential streets.
- Fulfilling a £48m ultra low emission bus scheme funding round to accelerate uptake and deployment of supporting infrastructure
- Launching a second round of funding for local authorities to roll out dedicated taxi charging infrastructure. Making available a minimum of £6 million to support more local areas to make the switch.

In addition to these initiatives the policy considers continuation of older programs such as the "Electric Vehicle Home Charge Scheme" that provides grant support for EV drivers installing a dedicated domestic EV charge point. Most of the mentioned actions are aimed to either electric vehicle infrastructure, EV investment subsidy or R&D, to address the barrier of high upfront cost of new vehicles and to accelerate the development of the enabling technologies and infrastructure require to achieve their ambitions. In the policy document, these actions are usually described in the parts:

- Part 2b: Driving uptake of the cleanest new cars and vans
- Part 2d: Putting the UK at the forefront of the design and manufacturing of zero emission vehicles
- Part 3a: Developing one of the best electric vehicle infrastructure networks in the world

7.1.3 *Initiatives that involve industry and consumers*

As the Road to zero strategy is meant to be industry and consumer led, some of the announced actions are design with them in the center or are resulted from previous consultations. From the list we highlight:

- Consulting on reforming Vehicle Excise Duty to incentivize van drivers to make the cleanest choices when purchasing a new van
- Launching a 2018/19 Go Ultra Low campaign and continuing to work with industry on consumer communications about ultra-low emission vehicles until at least 2020.

- Setting up a new Road Transport Emissions Advice Group, bringing government, industry and consumer groups together to help ensure clear and consistent consumer messaging and advice on fuel and technology choices
- As set out in the Clean Air Strategy consultation, legislating to enable government to compel vehicle manufacturers to recall vehicles for an environmental nonconformity or failure, and to make tampering with emissions control systems a legal offence
- Launching a call for evidence on particulate emissions from tire, brake and road wear to improve our understanding of these emissions and consider options for how they might be reduced.
- Introducing a new voluntary industry-supported commitment to reduce HGV greenhouse gas emissions by 15% by 2025, from 2015 levels.
- Launching a joint research project with Highways England to identify and assess zero emission technologies suitable for HGV traffic on the UK road network.
- Launching an Electric Vehicle Energy Taskforce to bring together the energy and automotive industries, in order to plan for future electric vehicle uptake and ensure the energy system can meet future demand in an efficient and sustainable way.
- Launching an electric vehicle charge point design competition

7.1.4 Another initiative related to digitization

There is another action worth noting in the Road to Zero strategy, the one related to the Automated and Electric Vehicles Bill. With this bill the government will ensure:

- That charge points are available at motorway service areas and large fuel retailers
- That charge points are easily accessed and used across the UK. This includes powers to provide a uniform method of accessing public charge points and refueling points; make certain information publicly available in an open and transparent format and set reliability standards
- That charge points are smart ready by giving government powers to set requirements prohibiting the sale or installation of charge points unless they meet certain requirements.

This is relevant because it would address some of the technological (from an interoperability perspective) and social barriers around electric vehicles and smart charging networks.

7.2 South Korea: “The Korean New Deal”

In April this year, the South Korean Government announced the Korean New Deal (Ministry of Economy and Finance of South Korea, 2020), promoted by the South Korean Ministry of Economy and Finance, whose strategic program lays the foundations for digital transformation at the national level after the COVID-19 crisis for the next 100 years, in order to position South Korea as a world economic leader, moving from a carbon-dependent economy to a green economy and transforming society into a more inclusive one. This initiative is one of the first medium and long-term strategies to react strongly to COVID-19.

The program aims to take advantage of the growing demand for "contactless" services resulting from COVID-19 to transition to a digital economy. Throughout 2020 it has already become clear how it has had to migrate to online services so that the economy does not stagnate, with traditional service industries and small and medium-sized manufacturing companies with less digital capacity being the most affected by the pandemic. This accelerated transition to a digital economy can affect the competitiveness of industries and companies, requiring investments in digital infrastructure. Additionally, as the world grapples with this pandemic, it begins to recognize the need for climate action. The transition to an economy with an environmental conscience brings with it an improvement in the quality of life of people, but also allows the creation of new industries and jobs, being able to promote the economic recovery from the pandemic through green investments. It is even considered that those companies that adopt environmental policies in their processes generate a competitive advantage in the global value chain.

On the other hand, the promotion of a digital and green economy diversifies the ways in which it works, being able to do it remotely thanks to the use of technologies and platforms. However, it puts the job supply of low-skilled labor jobs at risk, creating the need for a job safety net that provides advanced job training while protecting new types of employment.

The program considers three fundamental pillars: Digital New Deal, Green New Deal and Stronger Safety Nets, which is intended to translate into a total of 28 projects (12 for Digital New Deal, 8 for Green New Deal and 8 for Social Safety Nets). The entire program includes a fiscal investment of 114.1 trillion won, with a total value of 160 trillion won adding the contribution of the private sector, and the creation of 1.9 million new jobs by 2025. This fiscal support it is accompanied by regulatory improvements driven by the private sector.

The investment will be made in a divided way. With an initial investment of 6.3 trillion won, during 2020 the execution of those projects that help to overcome the crisis or that can be implemented immediately will be prioritized. During the years 2021 and 2020, an expansion of investments will be made for the new growth path, reaching a total of 67.7 billion won and the creation of 8,887,000 new jobs. In the last tranche, that is, between 2023 and 2025, the investment will be liquidated to solidify the new growth path, investing 160 billion won and creating 1,901 million jobs.

Figure 21 shows the general description of this initiative, where the 10 most relevant projects of the program and the relationship between the fundamental pillars mentioned above are also explained.

The New Deal Digital is expected to build a large-scale ICT infrastructure, including a "data dam," which serves as the foundation for a digital economy. This policy aims to promote a data-driven economy, including data collection, standardization, processing and combining, as well as ensuring a competitive advantage for South Korea through the creation of new industries and the acceleration of the digital transition of key industries.

Furthermore, the objective of the Green New Deal is to achieve net zero emissions and accelerate the transition to a green economy, promoting the use of low-carbon and decentralized energy. As part of this pillar, the construction of green energy infrastructures that promote energy saving and greater use of renewable energy is planned, as well as the strengthening of mobility, energy, technology, and other types of environmentally friendly industries.

The focus areas for each of the Korean New Deal pillars will be presented below.

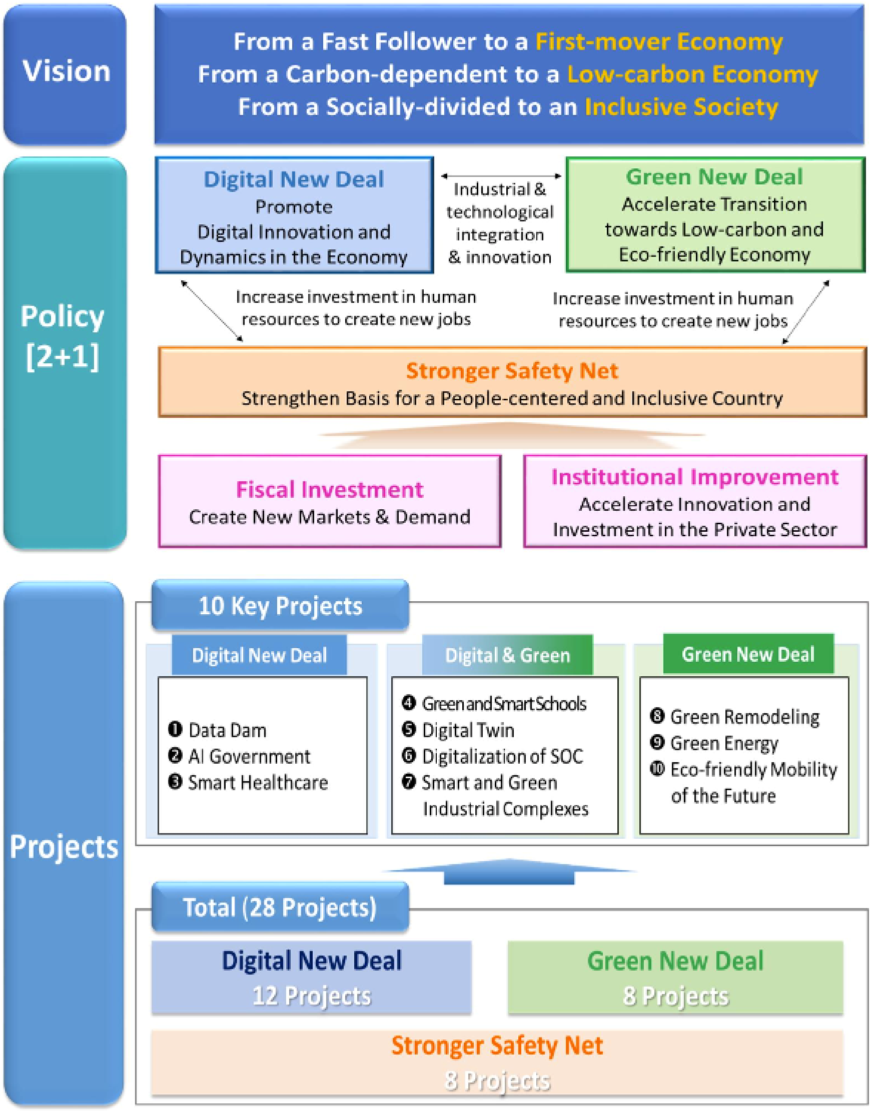

Figure 21: Overview of the Korean New Deal

7.2.1 *Digital New Deal*

Figure 22 summarizes the justifications behind the Digital New Deal, as well as the focus areas.

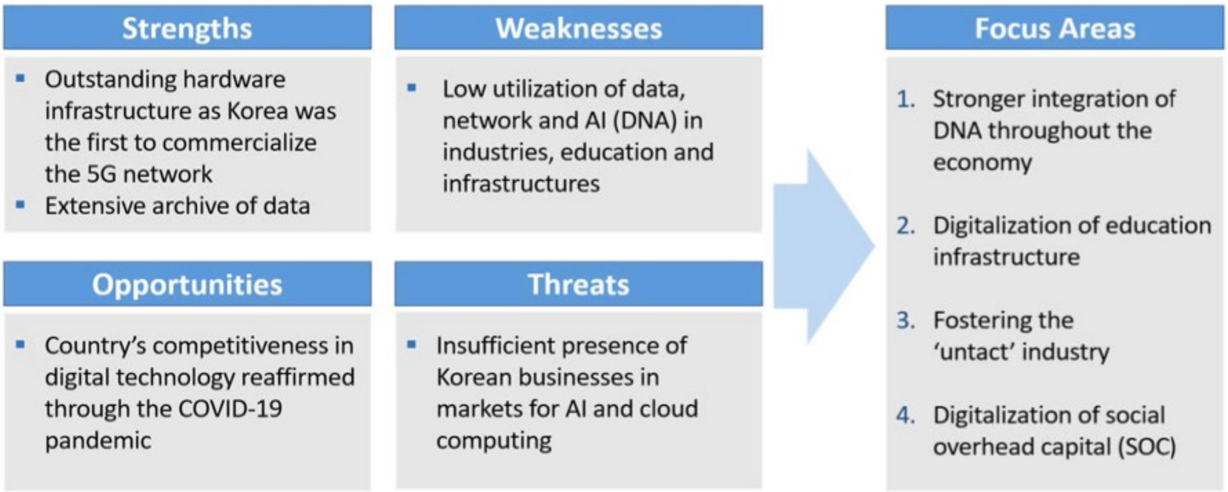

Figure 22: Overview of the Digital New Deal

"Stronger integration of DNA" into the economy refers to promoting the use and integration of data, the 5G network, and artificial intelligence to create new products and services, increasing South Korea's economic productivity. To do this, data will be collected, disseminated and used in areas closely related to people's lives (such as manufacturing or medicine), strengthening the data ecosystem. In addition, a data control tower will be established that will allow the management of public and private data in an integrated way. The establishment of large data platforms for different sectors is also included.

Likewise, it includes the incorporation of projects that integrate 5G and AI technology for the digitization of all industries and the creation of new markets, for example: 160 smart museums and galleries based on ICT will be built, the commercialization of autonomous vehicles will be developed, 12,000 smart factories will be built, medical image readers will be incorporated, among other projects. Added to this is the incorporation of these technologies into government work environments, in order to provide personalized public services. For this, it is intended to implement pilot projects based on blockchain technology and move to cloud computing of the public information system. Finally, cybersecurity will be strengthened throughout the country, providing support to promising companies and technologies in relevant areas, through personalized security consulting services to 6,650 SMEs, the distribution of security models to 500 industrial sites for integrated technologies, among other projects.

The "Digitization of Education Infrastructure" approach aims to expand digital infrastructure and educational materials to generate school, university and job training institution learning environments, incorporating a combination of online and offline methods. The projects that are incorporated with this approach are: to provide full coverage of high-speed Wi-Fi in the classroom in schools throughout South Korea, modernization of electronic devices (200,000 computers and 240,000 tablets) for the use of the program of "texts online ", launch of an integrated platform that provides public and private learning materials at the school level, replacement of old network facilities in 39 national universities, installation of education support centers and training centers, holding 2,045 conferences that will address the demands of the Fourth Industrial Revolution (including topics related to AI and robotics), and finally, the comprehensive job training platform called Smart Training Education Platform will be improved, thanks to the development of e-learning programs and virtual training.

The third approach of this policy, "Fostering the 'Untact' Industry", seeks to lay the foundations to promote this type of industry through the creation of infrastructure that is closely related to the daily life of citizens, that is, medical infrastructure, labor and commercial. Among the outstanding projects of this approach is the construction of 18 smart hospitals, capable of monitoring hospitalized patients in real time; IoT sensors (heart rate meters, blood sugar levels, among others) that allow monitoring chronic patients will be distributed among the elderly and vulnerable people; remote work in SMEs will be strengthened through consulting services to 160,000 companies; An accompaniment program for micro-businesses will be provided through pilot projects on subscription services and the integration of technologies based on 5G and AI, in order to establish 100,000 smart stores (with "contactless" ordering systems).

The last axis of the Digital New Deal, "Digitalization of Social Overhead Capital (SOC)", refers to the application of ICTs to the SOC infrastructure in order to add "smart" components to urban spaces, industrial complexes and logistics systems to strengthen industrial competitiveness. Through this approach, an intelligent management system will be built in four sectors: transportation, where a Cooperative-Intelligent Transportation System (C-ITS) will be adopted on the main roads, IoT sensors will be incorporated in all railways and will be established digital management systems in 3 fishing ports; geographic information system, accurate roadmaps and complete 3D maps will be developed to 15 types of underground structures, and measurement instruments will be installed in underground conduits of utility pipelines; For the safe management of water in rivers, reservoirs and dams, remote control and monitoring systems will be established in real time; Finally, for disaster management, 510 early warning systems will be installed in high-risk areas, as well as additional flood warning systems in 180 parking lots located near high water levels (this project is linked to smart parking). Regarding smart cities, 108 platforms will be installed that use closed circuit televisions (CCTV) to manage traffic and prevent crime in urban areas, the use of smart pedestrian crossings, transport that responds to demand and delivery with drones, and Two smart city pilot projects will be implemented. Regarding Smart Industry, for the real-time monitoring of security, traffic and crimes, integral control centers will be established in 10 industrial complexes, and remote monitoring systems will be implemented to control the leakage of toxic chemical substances in 15 complexes old industrial.

7.2.2 Green New Deal

Figure 23 shows the strengths, weaknesses, opportunities and threats, recognized in the Green New Deal, as well as the three focus areas.

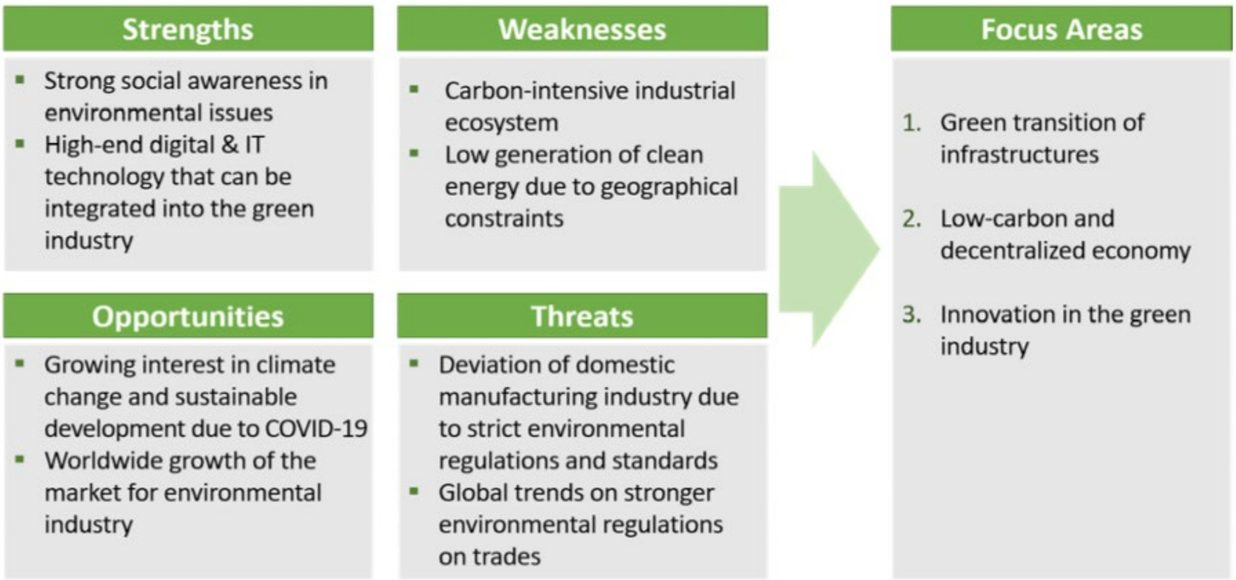

Figure 23: Overview of the Green New Deal

The first focus area of the Green New Deal is called "Green Transition of Infrastructures" and it aims to create ecological environments for the coexistence between human beings and nature. To achieve this, it is intended to transform public facilities into zero-energy buildings, using renewable energy and high-performance insulation, for example, solar panels and ecological insulation will be installed in 2,890 schools nationwide, thanks to public and private financing through the Build-method. Transfer-Lease (BTL). In addition, a comprehensive diagnosis will be carried out on the city's climatic and environmental challenges, which will serve to integrate customized solutions in environmental technologies and ICT in 25 regions by 2022. A smart water supply system (using ICT and AI) will be incorporated into 15 wastewater treatment plants by 2022, plus an urban flood control and wastewater odor monitoring project.

The "Low-carbon and Decentralized Energy Supply" approach will make active investment in R&D facilities that promote the use of sustainable and renewable energy throughout South Korea. It is intended to build a smart grid through the incorporation of AMI systems for the energy management of 5 million apartments. In addition, the system for measuring wind conditions will be modernized and feasibility studies will be carried out for the installation of offshore or onshore wind farms. Renewable energies at the community level will be promoted through loans in agricultural areas and renewable complexes, in addition to financial support to 200,000 households for the installation of DG in residential or commercial buildings for private use. In those regions where the renewable potential is not adequate, other solutions will be introduced that support the mitigation of emissions, promoting, for example, green mobility. In relation to mobility, 1.13 million electric vehicles will be provided (buses, cargo vehicles, among others) and 45,000 charging points will be installed; likewise, 200,000 hydrogen vehicles will be provided along with the installation of 450 charging points for these vehicles. This program also includes a plan for the scrapping of cars with diesel technology and the transition to liquefied petroleum gas or electric vehicles.

The latest focus area, "Innovation in the Green Industry", aims to build infrastructure that supports areas of the industry that strategically address climate change and environmental risks. To this end, they will support those SMEs in the environmental and energy sectors for the development of R&D, testing and marketing. 10 platforms will also be established for real-time monitoring and control of energy generation and consumption, through data collection, visualization of energy flow and the operation of an integrated control center. Regarding the monitoring of emissions and smart waste, a regional center will be established for the technological development, testing, manufacturing and marketing of solutions for clean air, biomaterial, hydrothermal energy, future waste resources and recycling of resources. Facilities that prevent fine dust in 9,000 companies will also be supported, in addition to the development of technology for the comprehensive management of fine dust in Northeast Asia, through regional cooperation. Finally, the recycling of resources will be promoted through support in the development of remanufacturing technology.

7.2.3 Stronger Safety Net

The analysis that inspires the latest Korean New Deal policy is presented in Figure 24, as well as its main working approaches.

Figure 24: Overview of the Stronger Safety Net

The first focus area, "Employment and Social Safety Net", seeks to protect vulnerable people in times of crisis, in addition to creating a strong and close employment and social security network, which will consider atypical forms of employment, such as artists and freelancers. Workers' compensation insurance will be expanded to cover an additional 88,000 workers (non-standard jobs), and eligibility criteria for basic safety benefits will be relaxed by 2022. Job search and job training programs will be expanded, through the incorporation of subsidies. In addition, labor costs will be subsidized to companies to promote youth employment in IT-related fields, in addition to the creation of a short-term internship program for young employees.

The "Investment in Human Resources" focus seeks to invest in human resources for the development of talent and employment support for new types of work, in order to reduce the digital divide by training 100,000 people in AI and software. Graduate schools specialized in climate change and ecological engineering will be created, allowing the training and job training of 20,000 people in integrated ecological fields. Likewise, training programs will be offered on industries of the future and the integration of new technologies in industrial environments. Support will be provided in the training of SMEs through digital-based training platforms. All the above is accompanied by the construction of an ultra-high-speed Internet network in 1,200 rural villages, including islands and other remote areas, which will allow Internet access to people throughout South Korea. In addition, 41,000 high-performance Wi-Fi equipment will be installed in public places and 6,000 digital capacity-building centers will be established, which will provide digital education to all residents.

As stated in the previous paragraphs, the Korean New Deal constitutes one of the most extensive and ambitious programs in terms of digitization, with scope not only in energy sectors as it is proposed as a global vision for the implementation of measures.

7.3 Singapore: "Smart nation initiatives"

This policy encourages digital transformation in Singapore, with the vision that this "Smart Nation is a leading economy powered by digital innovation, and a world-class city with a Government that gives our citizens the best home possible and responds to their different and changing needs" (Smart Nation Singapore, n.d.-c). This initiative has the support of the government through "Smart Nation Singapore", seeking to guarantee that the entire Society can benefit from new digital technologies considering three pillars: "Digital Economy", "Digital Government" and "Digital Society" (Smart Nation Singapore, n.d.-a).

Since the main driving force behind this policy is the government, it can be considered that its plans are classified as governmental and there is the participation of multiple agents, such as citizens, private companies, organizations, etc. To more specifically identify the participating agents, the Figure 25 (Smart Nation Singapore, n.d.-b)

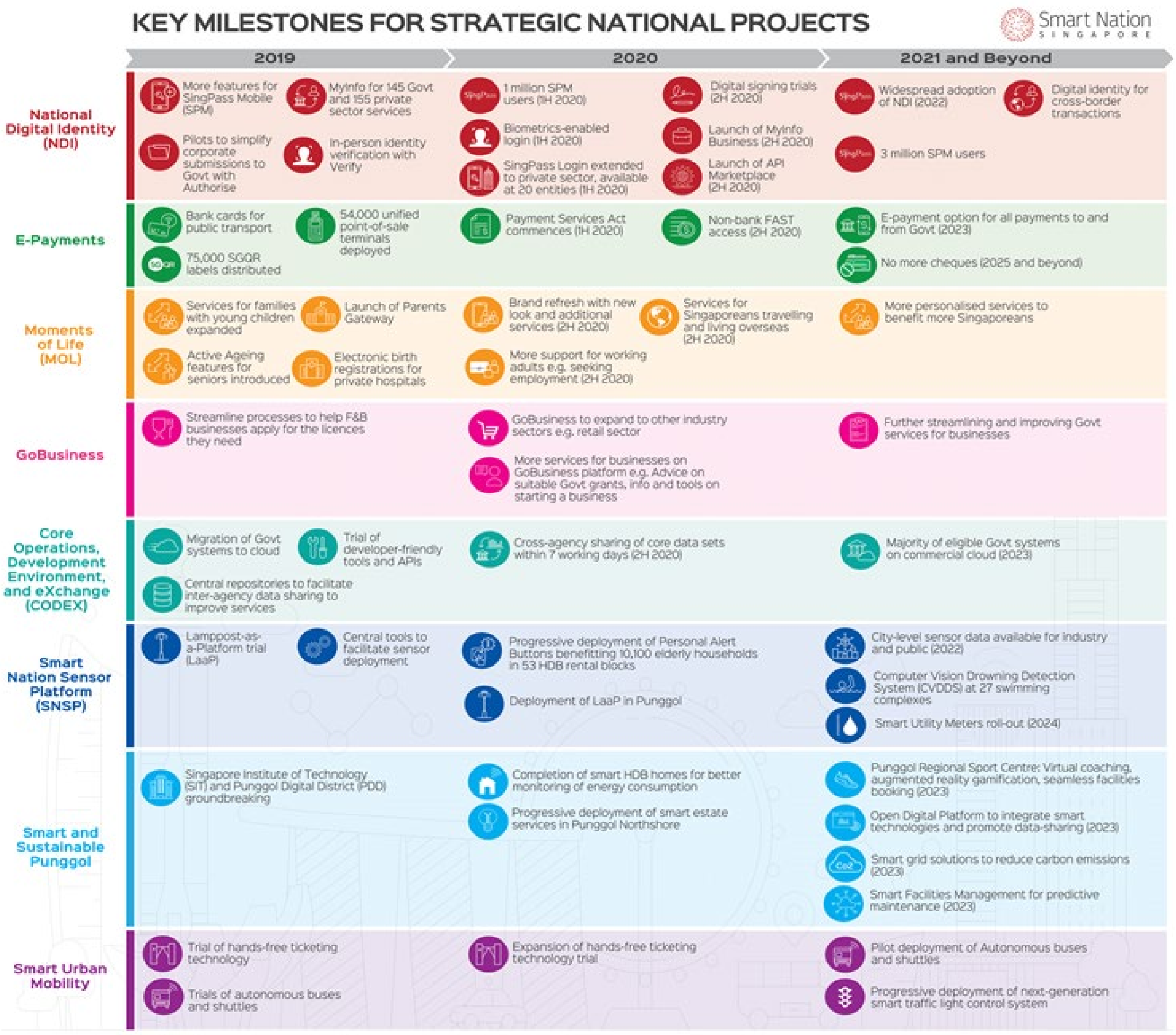

Figure 25: Strategic National Projects in Singapore

Within this transformation, changes such as "Open Data" have been included, which establishes that the information collected by public agencies is available to the public through online portals so that citizens can participate and co-create solutions. Linked to the co-creation of solutions, it also seeks to accelerate the industry and Start-ups, an example of this is the JTC Launchpad. The importance of cybersecurity and data privacy in this transformation in Singapore is also emphasized, in addition to promoting programming learning in the population so that they can take advantage of new digital technologies.

In the Smart Nation Initiatives six are specifically defined: Strategic National Projects, Urban Living, Transport, Health, Digital Government Services and Startup and business. From the initiatives and their corresponding projects, the intersections with the uses analyzed in this report are evidenced, below it is described how the "Smart Nation Initiatives" policy promotes different uses through the projects that are related to digitization of the energy sector.

7.3.1 *Strategic National Projects*

Among its projects is the Core Operations Development Environment and eXchange (CODEX), which highlights the benefits it provides in security through the adoption of common tools and standards, attacking the security barrier in uses that involve user participation, such as Energy Management, DSM / DR, Shared mobility, among others. In addition, the government can tap into what the commercial cloud can offer in scalability and reliability, facilitating the Development of user-centered services such as P2P trades, Retailing, Billing & Customer Orientation or Energy Management.

Another Project of this initiative is the E-Payment, in which in 2018 the Singapore Quick Response Code (SGQR) standard was implemented, which allows accepting payments through a QR Code, which can be an advantage in the implementation of the Shared mobility, being this payment method a benefit as you only need a cell phone to pay the use of the vehicles. On the other hand, it can also be useful for public transport, allowing also to pay through this QR Code. Linked to this is also the National Digital Identity (NDI) Project, which is a system to transact digitally with the Government and private sector in a convenient and secure manner, facilitating vehicle loans (shared mobility).

The Smart Nation Sensor Platform Project is also mentioned, which seeks to create a network of sensors at the national level to improve municipal services, city-level operations, planning and security. The portal mentions that "More systematic use of sensors and data to improve urban planning, build more responsive and reliable public transport, and better public security". From this it is evident this Project promotes the uses of public transport, and the network of sensors is very useful for uses such as smart lighting, smart traffic, smart parking, smart farm, smart waste management, smart industry and smart fleet management.

On the mobility side, there is the Smart Urban Mobility Project, which seeks -through digital technologies- to enhance comfort, convenience and reliability of our public transport systems. Based on its specific objectives, it is evident that this Project directly promotes smart traffic, analyzing anonymous data to manage traffic and administer bus fleets, also promoting Smart Fleet Management. It also proposes a "hand-free" payment system for public transport, which can also be complemented with the use of the aforementioned QR codes. This Project also seeks to achieve the correct implementation of Autonomous shuttles, thus promoting the use of "Autonomous Vehicle" (illustrated in Figure 26).

7.3.2 *Urban Living*

The first Project mentioned for this initiative is the Automated Meter Reading (AMR) Trial, which seeks to give users accessibility to information on water consumption using smart water meters, designed to monitor and extract water consumption data. This information is displayed through a mobile application, allowing understanding of water use and alerts for water leaks. This Project promotes the use of smart home & building by allowing management and monitoring of water consumption at the residential level (illustrated in Figure 27) or smart farming by facilitating the monitoring of crop irrigation.

Another Project that promotes uses linked to the Digitization Project is "myENV", which seeks to provide users with environmental information according to their location. In the case of this Project, the contribution would be to Emission monitoring, since it is mentioned that users can participate as volunteers, providing information for the environmental reports generated for the monitoring of emissions. On the other hand, by making people participate by giving them environmental information and allowing them to contribute, the use is also being promoted from a social perspective by bringing it closer to the population.

This initiative also considers the Project "Planning for Our People and Businesses" in which -within other objectives- it seeks to use the GEMMA tool to carry out studies of land use scenarios and infrastructure preparation plans. In this way, land use and transport planners can evaluate public transport use patterns in different locations to improve plans that encourage public transport use.

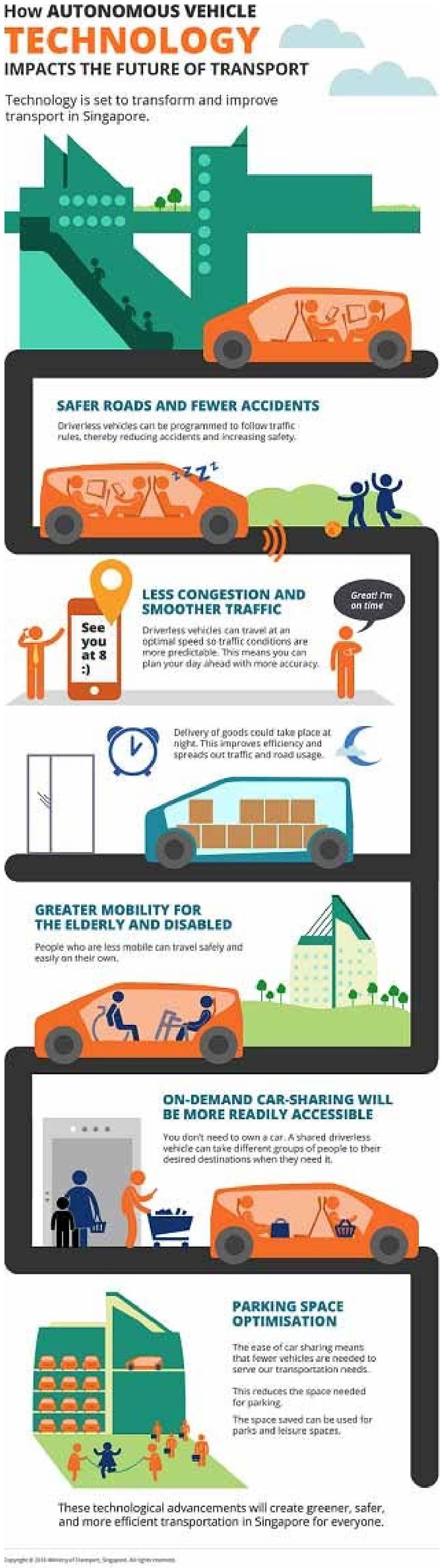

Figure 26: How Autonomous Vehicle Technology Impacts the Future of Transport

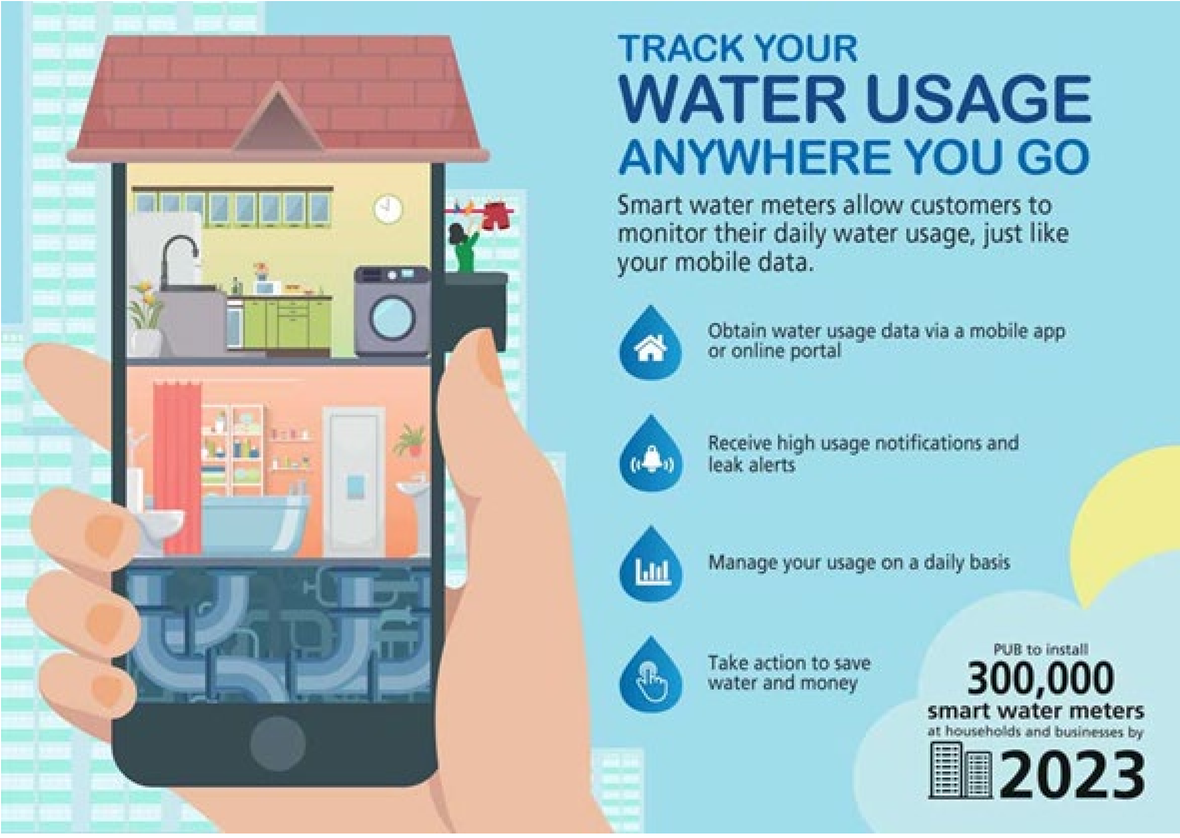

Figure 27: Illustration of Automated Meter Reading (AMR) in Singapore

The Smart Town Project has multiple axes, some of them are "Smart Living" and "Smart Environment", which promote the use of Smart Home & Building and Energy Management respectively. The latter, by using sensor networks that measure temperature and humidity, seeks to create a more pleasant environment for residents, which could be with Energy Management for heating. While Smart Living directly promotes Smart Homes as the following is mentioned: "digital infrastructure in flats to pave the way for intelligent homes. Residents will be able to tap on smart home applications developed by commercial companies". On the other hand, this Project also mentions "Sustainability efforts", explicitly mentioning the Smart Lighting that is sought to achieve through sensors, or the "Pneumatic Waste Conveyance System" which is an automated waste collection system to collect household waste, promoting the use of "Smart waste Management".

Another use promoted by this initiative is the distributed generation, because through the "Virtual Singapore" Project it is sought to create a 3D platform for the country, being one of the objectives the study of the solar potential of certain buildings to promote this type of generation.

7.3.3 *Transport*

Within this initiative there is a Project dedicated exclusively to autonomous vehicles. In the initiative portal, multiple autonomous vehicles already implemented in Singapore are mentioned and cover both public and private transport, also considering autonomous trucks. To promote this use, Smart Nation Singapore has collaborated with different institutions: A * STAR's Institute for Infocomm Research (I2R), National University of Singapore (NUS) and the Singapore-MIT Alliance for Research and Technology (SMART), nuTonomy, ST Engineering, Nanyang Technological University (NTU), ST Kinetics, Toyota, Katoen Natie and VDL. Linked to autonomous vehicles, the "Spearheading research in standards for SDVs" also stands out, which seeks to promote the development of self-driving vehicles for shared transport through research in standars. Regarding the latter, it is expected that through the CETRAN Test Circuit they will strengthen the image of Singapore as a living laboratory so that self-driving vehicles are tested and certified.

In addition, the Contactless fare payment for public transport is developed, in the portal it is mentioned that: "using long-range Radio Frequency Identification (RFI) technology to detect a commuter's fare card and deduct fares automatically as they pass a sensor", so that the payment of the public transport is more comfortable, directly promoting this use.

Another aspect that is considered in the transport initiative is the “On-demand shuttle”, which seeks to optimize transport times through algorithms that ensure that public transport buses have dynamic routes (from an application illustrated in Figure 28), picking up passengers at specific points and achieving better routes. This use promotes both public transport and smart traffic by managing the use of buses in real time, on the other hand, it can also be considered to promote smart fleet management, since by having the information of users who are using certain public transport routes, the way bus fleets are arranged can be better managed.

Figure 28: Application designed for “On-Demand Shuttle” in Singapore

Another aspect considered in this initiative is the "Open Data & Analytics for Urban Transportation", which seeks to manage bus fleets through data obtained anonymously, sensors and real-time location of buses, being the objectives of this policy the reduction of overcrowding in public transport and also the reduction of waiting times.

7.3.4 *Start-up and Business*

In the Project "Data Innovation Program Office (DIPO)" a pilot of data collaboration is in development. It seeks to build a decentralized platform that provides access to data with the consent of the data owners, promoting the sharing of data in a collaborative way. Therefore, this Project promotes uses in which the collaborative use of information by different agents of the System is required, such as DSM / DR, P2P trades, or market management & operation. On the other hand, the “Open Data” mentioned at the beginning of this section is part of this initiative through the “FinTech Sandbox” Project.

It is important to note that there are initiatives and projects not mentioned (e.g. the "Health" initiative and all its projects), this since they have no direct relationship with the uses studied for the digitization of the energy sector.

8 Gaps, barriers and opportunities identified at the national level

In this section, analysis is focused on the gaps, barriers and opportunities at the national level, for each digitalization use/application class. With the gaps recognized for other countries, and the opportunities offered by technologies/applications related to digitization, the possible goals to be achieved in Chile for each class are presented, taking into consideration Chile's current status. These goals are inspired by what other countries have achieved or could achieve, the barriers that applications have to face, as well as the barriers that should be addressed by public policy are also presented. Finally, the opportunities that were identified for different digital uses/applications in the international arena are evaluated for their replicability at the national level. The focus of this section is on those sectors that are of strategic importance to the country's development model.

In order to facilitate reading, applications and uses are styled in **bold**, enabling technologies are styled in *italics*, and public policies are underlined.

8.1 Smart Grid

8.1.1 Opportunities

Smart grids technologies present a great opportunity for both urban and rural zones in Chile. In cities, these technologies can enable consumers to provide services to the grid in a way that would be technically challenging or unfeasible otherwise and take advantage of resources such as PV panels on roofs and electric vehicles. On the other hand, in rural zones, both "on grid" and "off grid" **microgrids** have been used as an energy solution for communities that are far from distribution networks and have poor electric supply, o no supply at all, in many cases promoting sustainable energy sources and local development. Reliability and resilience can also be improved by better control and communications systems in **smart substations and feeders**. This is especially important in a country with such history of natural disasters and peculiar geography as Chile.

8.1.2 Breaches and goals

The 2015 roadmap Energía 2050 mentions that intelligent communication and control systems would be needed in order to achieve higher penetration of renewable energy sources, especially in urban and rural edifications, and set a target to get 100% of smart metering by 2050, it also points out the slow development of **microgrids**.

There are political efforts to make the electricity system more flexible and smarter. An example of this is the recent reform proposal for the distribution system at the national level, where one of its bills establishes the right to electrical portability, where end-users will be able to access different rates according to their needs. For this, it is necessary to modernize the measurement equipment in order to effectively deliver data with an hourly resolution to the agents that require it. Other efforts are yet to be published as the Quality of service bill that is part of the distribution reform, and new technical normative such as the new Minimum Design Requirements for Transmission Facilities which incorporate specifications on **smart substation** topics.

8.1.3 Barriers

The implementation of smart grid technologies can be fostered with establishment of economic incentives to the participation of flexible and modern resources in all energy markets (energy, capacity, and ancillary services) that effectively reflect the value of their flexibility, via the modernization of technical normative and regulatory reforms where needed.

On the other side, the actual coverage of telecommunication networks is concentrated in big cities and varies significantly throughout the Chilean territory, a more coordinated planification between telecommunication infrastructure and public services, among them electricity, could improve the development of smart grids uses.

8.2 Distributed Energy Resources (DER) Management

8.2.1 Opportunities

The growing penetration of renewable energies at the national level brings with it opportunities for new uses associated with distributed resources. By increasing the amount of resources in the distribution network, new challenges and needs arise for the network that once provide opportunities for innovation in the digitization of uses of this kind.

A clear example of this is the need to implement **VPPs** to efficiently manage the new DERs -whose costs are decreasing- that will enter the system as established in the decarbonization plan, whose variability will be relevant at the time of operation, giving a space for the use of **Energy Storage** to absorb the imbalances that occur. It is important to point out that **Energy Storage** becomes economically competitive if the amount of **distributed generation** increases, so the Chilean decarbonization plan directly provides an opportunity for this use, in addition to the potential to use the Lithium that Chile has.

On the other hand, the use of emerging technologies such as *Big Data*, *Cloud Computing* or *Artificial Intelligence* are also an opportunity for the uses of this class to improve their operation, in addition to obtaining information (with the prior authorization of customers) that could be useful for fields outside the energy sector.

The entry of these new uses in the Chilean energy sector gives rise to new services to consider in the energy market, such as the **demand response** for the possibility to do load shifting, in addition to the use of **energy storage** for contingencies or during peak hours, lowering operating costs.

Based on the above, the measures that Chile has taken as part of its decarbonization process allow the entry of these uses, such as the goal of reducing 30% of GHG emissions by 2030, or the creation of the Table for Retirement and/or Conversion of Power Plants to Coal. Through these goals, the aim is to transform the energy crisis into an opportunity, being the most relevant measure of the measures taken by the State the goal of having 70% renewable generation by 2050, as this implies the integration of these uses to the network and to the market. Regarding the new technologies associated with data management that can be complemented with the uses of this kind, in Chile initiatives have been taken that facilitate their entry and although they are not initiatives related to the energy sector, they are indirectly linked to it through its support for uses, some of these initiatives are The State Modernization Process, Digital Agenda 2020, Digital Government, National Cybersecurity Policy and the Data Observatory, Ministry of Economy.

8.2.2 Breaches and goals

To determine the gaps in the Chilean case for uses of this kind, decarbonization plans and initiatives to combat the climate crisis through new uses such as **DSM** or **Energy Storage** should be taken into consideration, highlighting goals such as the use of **distributed generation** and **demand management** by the public, commercial and private sectors for the year 2050, according to the goals established in Energía 2050, a document focused on the country's energy policies. As in the case of barriers, there are gaps that are inherited in the Chilean case, such as connectivity and access to information, considering that uses such as **distributed generation** or **DR/DSM** require access to consumer information / generation by end users that is currently not possible in the absence of *smart meters*, so one of the gaps in this area is to reach a greater implementation of *smart meters*, which in turn helps to meet goals such as a greater participation of end users and a greater amount of **distributed generation**. However, it should be noted that the DR/DSM might not use smart meters, direct load control (DLC) is also possible, so the goal of smart meter intelligence can be relaxed in terms of DSM, but it should be taken into consideration higher resolution measurements.

On the other hand, **Energy Storage** also appears as an option for the future, but it is highlighted that for this to be a reality, it is expected that technological advances should facilitate its incorporation, which can also be added to the use of Lithium as a resource for this use. With this eventual increase in **Energy Storage** in the Chilean system, it is also expected that the role of

prosumer of households will become more relevant. Linked to the previous analysis that is based on Energy 2050, in this document it is also mentioned that in the future there should be greater technological surveillance for the monitoring of storage and facilitate the role of prosumer at the residential level.

For the particular case of **VPPs**, no particular goals / gaps are specified, however, it is expected that - analogous to the international case - greater accessibility to the Internet will be achieved by the resources that are managed through this virtual plant. Furthermore, improvements in **forecasting** and **monitoring** technologies are expected for a better performance of this use.

The uses of this class are an important part of the decarbonization plans of the Chilean energy sector, being some of the goals of this initiative the withdrawal of conventional plants. The desired state is one in which the presence of this type of generation is minimal, which is why it is expected that by 2024 the eight oldest thermoelectric plants in the country will stop operating, as indicated by the objectives of the Chilean energy decarbonization plan.

In addition, it is suggested that in the future it is expected to have decentralized production and active demand management. These advances in demand management are expected to be complemented by other uses of Smart Grid to help achieve the objectives of the country's Energy Policy. On the other hand, the goal is to move towards a bidirectional electricity system, so it is expected that the **distributed generation** and **demand management** come to be similar to other OECD countries as established by energy policy in Energía 2050.

Finally, cybersecurity gaps should also be considered, where the national cybersecurity policy considers the infrastructure associated with the energy sector critical (this particular sector is not discussed in depth in this policy). The goals in this aspect can be summed up in "having a robust and resilient information infrastructure, prepared to resist and recover from cybersecurity incidents", from which the subgoals to meet this objective emerge, some of them are the protection of the information infrastructure, having an infrastructure to respond to cybersecurity incidents or the Requirement of differentiated standards in cybersecurity.

8.2.3 *Barriers*

Based on the international analysis, there are barriers that are inherited from the uses associated with this class, the regulatory difficulties for the implementation of these uses imply a delay in their entry into the system despite its technical feasibility. An example of this is the entry of **VPPs** to the market, as it requires having the figure of an aggregator, which in the Chilean case is not currently part of the energy market (however, this is addressed in the distributed generation law). Linked to regulatory gaps are also economic gaps, associated with the high investment costs of **storage** today, which is why it is necessary to have more economic incentives for the entry of these uses.

On the other hand, there is another very important barrier to consider, which is the use of *smart meters* (one of the enabling technologies for the uses of this class), so not having these devices considerably limits the implementation of these uses in the Chilean system. Considering the complications that have occurred with the installation of *smart meters* in recent years, mistrust on the part of the population could slow down the implementation of the uses of this class and affect its effectiveness, as cannot collect the necessary user's information, thus limiting the number of distributed resources that actively participate in the network.

It should also be considered that these uses bring with them a withdrawal of conventional generators from the system. An accelerated withdrawal would put the security of the national electricity system at risk, in addition to increasing the use -during the transition- of gas and oil, increasing the marginal cost of the system and moving away from the desired environmental effects. Therefore, despite the technical feasibility of the uses of this class, the transition should not be accelerated to avoid the complications previously mentioned.

In addition, should be considered that the decarbonization plan encompasses the three pillars of sustainability (environmental, social and economic), so that although the retirement of conventional generation means a considerable environmental improvement, the loss of jobs that this retirement should also be considered of generators means for the communes in which these plants are located, however, this loss of jobs could be offset by the new job opportunities that appear when implementing the new uses, although it should be considered that this transition is not immediate.

Regarding the use of *Artificial Intelligence* for these uses, it also has barriers generated by the population's aversion to this technology due to the replacement in the workforce that can mean, in addition to their need for data extraction, which can violate privacy of the users.

8.3 Customer domain

8.3.1 Opportunities

Uses of this class can impact directly the customer's service experience and engagement with the energy sector as they can offer customer-tailored energy products with a wide range of incentives and features. Chile is a leader in the region in terms of internet connections per capita, the high penetration of mobile internet, in big cities like Santiago, could facilitate the enrollment of customers in attractive energy related programs such as *electric vehicle* charging networks, **demand response** programs, green-certified energy supply, local **P2P** energy markets, etc. From a technological point of view, *blockchain* is seen as an enabling tool for new energy assets and products to participate in energy markets.

8.3.2 Breaches and goals

Although there is no declared goal on uses of this class, the policy efforts in energy seems to be aimed to establish better market solutions for customers. The electric portability law and the new regulation on net-billing, that allows **prosumers** to benefit from their own remote energy resources or from shared resources within a community, are clear examples of the trend that is ongoing in the country, which is lagged in comparison with countries in Europe or the US.

8.3.3 Barriers

The barriers identified for customer domain's uses in Chile can be technical, economic and regulatory. From the lack of infrastructure to measure and trace energy use, to the lack of regulatory framework for market agents such as the retailer itself.

Other barrier seen in countries that have implemented liberalization on retail markets has been lack of competition. In this matter, the new law project about electric portability, which defines many aspects related to electricity retailing, has seen concerns expressed in the public discussion about how it would promote competition and efficiency, for example, on the allowance for the incumbent distribution company to participate in the retail market and the modernization of public tenders with "take or pay" components, among others.

From a digital perspective, the success of customer domain applications could depend heavily on closing the digital breach among population (mainly in terms of coverage and education), as people would probably need to access information, understand new products and services, enroll programs and even execute some form of participation, all via digital means.

8.4 Process Management

8.4.1 Opportunities

The incorporation of these uses entails an improvement in the efficiency of the processes through the deployment of equipment and technology. The effects for the system are greater if you work in the main source of generation in the country under study (for example, in Singapore 95% of electricity is generated with natural gas). The **optimization of production processes** could lead to an increase in the satisfaction levels of the employees and the creation of new job profiles.

A good measurement and constant **monitoring of the emissions** of a certain process, facilitates decision-making and mitigation actions according to the situation and context.

8.4.2 Breaches and goals

It is likely that there is resistance from employees to companies including **automation** initiatives, so it is recommended that their incorporation be done in an informed way and accompanied by programs that improve work skills (Fundación Chile, 2017).

The objective associated with the particular use of **emissions monitoring** in the countries analyzed is associated with the reduction of emissions, whose most recurrent goal is to achieve zero emissions by 2050 (updated NDC), for example through the Plan de Descarbonización de la Matriz, the gap being the amount of emissions that remain to be eliminated, shown for example in (IEA, n.d.). Regarding the use itself, it is mentioned that a gap to achieve its goal is the adoption of technologies that better manage uncertainty, such as those in **Forecasting and predictive analytics**, and a change in behavior and business ethics (the gap is the change itself, and the barrier is the resistance to be carried out by the business sector).

8.4.3 Barriers

The high cost of modernizing processes, through the necessary infrastructure and monitoring systems, constitutes a barrier, in addition to not being able to access all the necessary information.

On the other hand, there is a lack of economic incentives for the main pollutant emitters that can slow down the implementation of **emission monitoring** systems.

8.5 Mobility

8.5.1 Opportunities

The main opportunity presented by digitization in uses related to this class is its potential to reduce greenhouse gas emissions, aligned with Chile's commitment for GHG neutrality by **2050** in updated NDC 2020. Digitization can foster the adoption of *electric vehicles* in the extent to which it can generate added value to the owners (*vehicle-to-grid services*, *smart charging networks*, etc.). Promoting the adoption of *electric vehicles* is of utmost importance, since in Chile 98% of the energy used for transportation corresponds to petroleum derivatives, which makes this area responsible for almost 20% of total emissions in the country. On the other hand, digitalization favors the reduction of emissions by making the transfer of goods and people more efficient, reducing the number of simultaneous vehicles in the streets and the transit time of each vehicle, this is especially relevant in the country considering that, for example, in Santiago the rate occupation is 1.5 people per car. In addition to reducing greenhouse gases, digitization can improve transport safety by contributing to the decision-making process and the construction of public policies with quality data and can also promote the development of local innovation and new business models.

8.5.2 Breaches and goals

The entry into operation of Transantiago more than 10 years ago, brought with it the integration and massification of different digital applications such as use of applications to **control the fleet** and **online monitoring**, interoperability between different public fleet operators and different modes of transportation, digitalization of the payment system, information system for user, etc. This type of application has not become widespread in public transport in other regions of the country.

There has also been a mass use of applications to optimize (Example: Waze, Google Maps) and applications to promote the private means of transport, such as Awto, Uber and Cabify. It is still critical to resolve the constant disputes with other means of transport such as taxi and collective taxi transport. This type of application has also not become widespread in other regions of the country.

In the case of cargo transport, there have been companies for quite some time (WiseTrack, GPS-Chile, I-GPS, Black GPS, etc.) that offer digitization services such as cargo tracking through the use of GPS (a kind of *sensor network*, ancestor of *IoT*), optimization of routes, use of business intelligence tools, etc. Considering that the land freight transport market is quite atomized, it is expected that the introduction of those type of technology will be massive. The use of applications such as CamionGo (equivalent to Uber, Cabify for the transport of people) could help the integration of small companies to enter freight transport services.

In recent years, there has also been a massification of minor freight transport associated with electricity commerce through digital platforms such as Mercado Libre, Linio, supermarket applications, applications associated with home delivery of food and other types of products (Uber Eats, Rappi, Cornershop, etc.), etc. Although this type of application is overcrowded in large cities, there are still many cities without access to this type of technology due to the lack of a critical mass of potential clients.

One key enabling technology to support the upcoming digital applications in mobility are the **autonomous vehicles**. Different initiatives have been carried out to develop the current state of this technology in Chile, such as the first pilot of shared autonomous vehicle in Latin America and the Caribbean, carried out by The Bank Inter-American Development, the Ministry of Transport and Telecommunications of the Government of Chile and Transdev between December of 2019 and march of 2020. To this initiative is added the "Autónomo" contest, which will award 24,000 USD up to 3 projects that address any of the 8 proposed challenges[19]. In electric mobility, in Chile the objective is to reach 40% of private vehicles and 100% of public transportation by 2050, currently the share of electric vehicles is close to 0.1%. To achieve these objectives, policies and incentives have been implemented.

The Government of Chile considers public transport as one of the main axes within its Electromobility strategy. An example of this public transport commitment is that to date it has 383 electric vehicles operating in Santiago's public buses network and has the first exclusive terminal station for this type of buses. To encourage the use of private *electric vehicles*, the following benefits are in place: a green tax, exemption from vehicle restrictions, preferential parking and free charging points. Despite the low participation of *electric vehicles*, the current situation of electromobility in Chile is vastly superior to the one that existed a few years ago, this, added to the existing incentive policies and the ones yet implemented, forecast a better future.

8.5.3 Barriers

Economic barriers associated with the use of digital applications in public transport in regions and their impact on transport rates need to be solved. At the national level, no progress has been made in the development of interconnection networks between vehicles and the discussion on the communication standard is still an open discussion at the international level. In the case of freight transport, the fact that it is a fairly atomized market, it is necessary to spread digital technologies in this segment.

In the national context, different barriers can be recognized for uses of *electric vehicles*. For vehicles for personal use, the low adoption of electric vehicles (3,298 hybrids and 714 electric vehicles sold between 2012 and 2019) is mainly due to the fact that they have a higher initial value compared to conventional models, although their operating costs are lower. In this situation, conditions must be created so that the regulations encourage consumers to prefer *electric vehicles*, such as strengthening the charging network, limiting the movement of combustion models and defining a date on which the sale of models that use fossil fuels will be prohibited (as has been done in other countries). Another barrier for this type of vehicle is the prohibition of converting cars from conventional to electric, a process that is seen as an economical option to acquire this type of car. In between the mobility and the smart grid use, one can argue that a proper distribution of charging stations that weights the tradeoffs between availability of infrastructure to electric vehicles and imposing extra demand over the current electrical network.

Regarding **autonomous vehicles**, barriers to their implementation are the lack of regulation and infrastructure, these barriers are not unique to Chile since in general this technology is in stages of development around the world and its regulation must consider specifications for both the manufacture and operation of the vehicle, in contrast to conventional vehicles for which there can be separate regulations. Germany was the first country to pass a legal framework for the manufacture and use of these cars stating that there must always be a driver sitting behind the wheel, ready to take control if the self-driving vehicle asks for it.

8.6 Data Management

[19] 1) cybersecurity, 2) on board services, 3) demand simulator, 4) auto-dispatch system, 5) geo-location and detection, 6) customer identification, 7) reaction protocols and 8) implementation and calibration.

8.6.1 *Opportunities*

Chile has an incredible potential for renewable energies: the 2020 National Green Hydrogen Strategy indicates that the country's solar potential is around 1.7 TW, wind about 190 GW and hydroelectric run-off-river 6 GW, which in aggregate amounts for 70 times the current installed capacity that can be developed to produce the fuel of the future (Ministerio de Energía, 2020). Data management technologies present an important opportunity to take advantage of these energy sources, by being able to feed the **algorithms that predict** their behavior with data, and thus obtain accurate predictions that allow better planning and operation of these kind of power plants. There is also a great opportunity in the management of consumers data that could lead the policy making process in terms of better understanding of demand elasticity, demand forecasting, consume patterns and responsibilities in the peak hours, etc., these examples apply for electricity, transport and heating.

8.6.2 *Breaches and goals*

The main recognized gap is related to data acquisition, since for this the necessary infrastructure (e.g. *IoT & IoE*) and the adoption of technologies must be considered. In this sense, Chile has not made an explicit declaration, so it is expected that the incentive is mainly associated with companies that involve data management to **optimize their processes**, in terms of costs and security.

8.6.3 *Barriers*

The generation of public policies related to data management, in particular on the rights of people and the responsibilities of the *multiple agents* who manage them, is recognized as a barrier to the implementation of this type of use. In this sense, the Chilean state has already begun to work on different public policies associated with data sovereignty and strategies that establish the roadmap that allows the country to focus its efforts and talents in the search for a sustainable and ethical development of AI for the next 20 years, with a focus on Research (I) Development (D), Innovation (i) and its impact on Society (S). In particular, the work carried out by the Future Challenges Commission, through its *Artificial Intelligence* strategy, stands out (Gob.cl, 2019; Ministerio de Ciencia, n.d.). Regarding the rights of people over their data, there is an important possibility of incorporating this concept, for example, in the drafting of the new constitution.

8.7 *Smart city*

8.7.1 *Opportunities*

In general, the uses related to Smart City bring with them social benefits associated with an increase in social well-being, improved road safety, reduced travel times, better services, reduced visual and olfactory pollution, increased quality of life, among others. From an environmental point of view, Smart City contributes to the reduction of GHG emissions, through the efficient management of energy and water, the reduction of fuel consumption and the improvement of production processes. Opportunities are recognized in each of the possible uses of Smart City, promoted by the national government and local governments, with the active participation of industry and society. In addition, the development of emerging technologies that allow the implementation of these uses has shown a positive trend (e.g. *IoT, 5G, machine learning, big data,* among others).

8.7.2 *Breaches and goals*

In the Chilean context, there is a declared intention to incorporate technologies that target the benefits mentioned above. For example, in 2015 the government of Chile presented the Digital Agenda 2020, a project that consists of 63 measures that establish the guidelines for the country's development in this area during the next five years (Ministerio Secretaría General de la Presidencia, 2015). The initiative is divided into five axes: rights for digital development, digital connectivity, digital government, digital economy and digital skills. Within the axis of the digital economy, specifically measure 44, the concept of Smart City is incorporated. As part of the measure, a strategic map of the Smart City Plan was drawn up, the initiative was developed and pilots were implemented on prioritized issues, opportunities were identified and gaps were identified in smart cities within the framework of the Smart Industries Strategic Program, among other milestones. However, some of the proposed goals were not met, mainly due to the replacement of the Executive Power.

On the other hand, the Santiago Smart City program is a public-private initiative, promoted by the Metropolitan Regional Directorate of CORFO and Fundación País Digital, which has the support of various public bodies, private companies and civil society organizations, with the general objective of activating and articulating the generation of solutions around Mobility, Security, Environment and Enabling Resources for the city, through the implementation and use of Information and Communication Technologies (ICTs). This program starts in 2017 and runs until 2025, and consists of 3 stages: positioning, consolidation and institutionalization (CORFO, 2018). The initiative contemplates the identification of technological needs and trends, strengthening the innovation and entrepreneurship ecosystem, and generating solutions around the aforementioned issues.

Of the gaps recognized internationally, the need for security systems for compromised data in each of the applications related to Smart City stands out. Associated with this is the need for access to information that is currently not available. In this sense, the Commission Challenges of the Future, Science, Technology and Innovation considers incorporating policies related to cybersecurity and data sovereignty, which is mentioned in greater detail in the use **Data Management**.

Likewise, gaps have been recognized related to the costs of implementing the uses itself and their associated enabling technologies, which would also be significant at the national level, understanding that the current status on this issue is low. In this sense, the presence of important multinational companies in the electrical energy sector (for example Enel) is consolidated as a good opportunity to overcome the economic barrier, considering that these companies also have international experience associated with the implementation of Smart City.

Therefore, any implementation that takes place must consider the convenience of the public, otherwise the opportunity to improve people's quality of life would not be seized.

8.7.3 Barriers

As in other kinds of uses, the need for public policies and regulations that define the rights and responsibilities of each of the actors involved in data management. Likewise, a secure and resilient communications system must be guaranteed. In (Logicalis, 2018) different barriers associated with the adoption of *Internet of Things* (IoT) solutions at the Latin America business (included Chile) were identified: financial issue, organizational culture, lack of knowledge about *IoT*, absence of specialized providers, telecommunications infrastructure, low qualification of IT areas and the lack of trained workforce (3%) were the main identified difficulties.

In addition, the importance of generating spaces for pilot projects that allow testing the implementation of different applications related to Smart City stands out, in order to study their effects under the Chilean context. Added to the above is the implementation of programs that encourage the creation of innovation spaces, from where solutions adapted to the needs of the networks are designed. In this sense, it is highlighted that this constitutes a common practice according to national experience in related issues.

On the other hand, the state must become a participant in the transition to a smart city, through support programs and the generation of incentives that spread these uses. Added to the above is the tax work that generates economic incentives for companies and users to incorporate solutions related to Smart City.

Finally, it is important that those internet access goals imposed by the Chilean state are met, since it constitutes one of the most relevant barriers for any use of Smart City.

8.8 Other uses

8.8.1 Opportunities

The uses associated with this class have various opportunities specific to the variety of topics that are addressed. The generation of new markets and the increase in competitiveness in the existing ones that these uses imply are an opportunity for their implementation by allowing reductions in energy costs and their need to allow the entry of **DERs**.

The contribution to energy efficiency that these applications provide is also an opportunity in the Chilean context. As mentioned before, the goals associated with the climate crisis promote uses that contribute in this regard, which added to the imminent arrival of the *IoT*, gives space to the uses associated with this class to attract interest in the energy sector. It is important to mention that along with the increase in energy efficiency, a reduction in costs and improvements in system security are also achieved.

Its contribution to reducing emissions is also an opportunity in the Chilean case, thanks to the Decarbonization plan, the growing presence of **distributed resources** requires new and more sophisticated **ancillary services**. On the other hand, the reduction of emissions can also be linked to **teleworking**, since the reduction in travel times, in addition to being an opportunity in itself thanks to the time savings it offers to workers, also contributes to the reduction of emissions by part of private vehicles, and those generated by energy consumption in offices.

On the part of the state, it is emphasized that the contingency that has been experienced due to COVID-19 is an opportunity to advance in **teleworking** issues, which is why a law was enacted in March with the purpose of increasing the number of workers who use this modality. These measures are expected to promote **telework** by meeting European standards to guarantee workers' rights.

8.8.2 *Breaches and goals*

Linked to barriers, the gaps in the uses of this class are oriented towards infrastructure and data management. The implementation of these uses requires equipment for data collection and management, so it is expected to achieve improvements in the infrastructure for the correct implementation of the uses of this class, being the most obvious example the massification of *smart meters*, which is linked to the goals established in Energía 2050 in which part of the proposed improvements require *smart meters*.

In the case of **ancillary services**, as in the international case, each type of service has its own gaps, however, in the Chilean case there is a gap common to all, which is standardization, improvements in **ancillary services** brings greater complexity for the system in technical and economic terms, so it is expected that work will continue on normative and regulatory aspects, such as the distributed generation law. On the other hand, it is expected that the connectivity of the computers participating in the network will increase at the same speed at which the resources distributed in the network are increasing, so that the market and the system can respond in a good way to the modernization that is being carried out in the network.

Since these uses require a large amount of information, the State is expected to continue to implement cybersecurity policies. The uses of this class are also subject to the national cybersecurity policy, despite not being explicitly mentioned, since the goals established in this policy influence the implementation of these uses (e.g. "Implementation of standardized incident reporting, management and recovery mechanisms") and consider the energy sector as critical. Currently, they have already been implemented and there has been progress in this regard, even so, it is expected that there will be further development of policies to guarantee the security of user information, and also the security of the system against cyberattacks.

In the particular case of **teleworking**, it is expected -as in the international case- that there will be a considerable increase in the number of workers who use this modality, which also implies the implementation of new policies and laws such as those that have been enacted recently under the context of the pandemic (Ministerio de Salud, 2020), with a view to greater labor flexibility, partly addressed by telecommuting law. This increase in people working remotely implies gaps from both a public and private perspective, such as a greater implementation of technologies that facilitate this new mode of work, either by handing over equipment to employees or using new technologies such as the use of *Cloud services*. On the other hand, as part of the 2020 Digital Agenda, one of the goals is to reach 90% of households with fixed broadband (related to *LAN/HAN/NAN/WAN*), so it is expected that in the future this percentage will increase considering that the aforementioned goal must be met this year. In this use, the goals related to cybersecurity must also be taken into consideration due to the sensitive information that is now handled in other networks and equipment than the usual ones. The national cybersecurity policy addresses policies in this area where the telecommunications sector is considered critical, and some of the goals that can be associated with this use are the protection of the information infrastructure, the development of a culture of cybersecurity around education, good practices and responsibility in the management of digital technologies and an impulse in the country to develop a cybersecurity industry that serves its strategic objectives.

The current state of **teleworking** is “late” with respect to the goals as indicated by the undersecretary of labor (Meganoticias, 2020). This considers the aforementioned technological aspects, but also, in order to reach the desired state where **teleworking** is mature in Chile, training of the workers is needed. This is as relevant as the technological aspect, so that for the optimal use of the advantages of **teleworking** there must be programs by companies and/or the government where employees are trained so that working conditions and productivity are not seen negatively affected.

8.8.3 Barriers

The technological advances that would need to be implemented in Chile to take advantage of these uses are the main barrier for this class. For improvements in **ancillary services**, an update of the network is necessary so that the bidirectional flow and the changes produced by **demand response** are possible. If the necessary infrastructure such as *smart meters* is not implemented, or a greater presence of *AMIs*, the digitization of uses such as **Energy Management** or **Ancillary Services** is very limited.

In addition to the proper implementation of these new technologies, there are also social barriers associated with the uses of this class, the need to use personal data of users (*EV*, *DSM*, *Smart Homes*, etc.) can generate distrust in users, limiting the accessibility to relevant information for the operation of the system, or **Energy Management**. In this class *smart meters* are a barrier, since for all uses -except teleworking- these devices are relevant for their operation, so the complications with their implementation in past years drag with them a barrier for the digitization of these uses.

The use of user data also implies barriers associated with cybersecurity. The need to implement more policies to protect sensitive information from both users and the operator can slow down the implementation of these uses. For this, the implementation of government and business policies must be considered. It is important to note that the State is currently working on cybersecurity aspects that can be applied to the energy sector, such as cooperation agreements with the UK, or agreements with companies (CICS, 2019).

These new necessary policies and regulations will slow the implementation of uses of this class. In addition to cybersecurity, it is necessary to regularize its entry into the market, although this is in process and *multiple agents* such as the demand aggregator are being introduced, there are still areas that need to be addressed in depth, such as the incentives to incorporate these new technologies and their entry into the market, or obligation and incentive for companies in the energy sector to share data that may be useful for uses of this kind.

In the particular case of **teleworking**, the barriers identified coincide with those found in the international analysis. The ambiguity between times and work spaces can negatively affect the productivity, mental health of workers and the sense of belonging to a work group, these impacts being a social barrier that could reduce the amount of work carried out in this modality. At the same time, the aforementioned ambiguity makes it necessary to regularize it. In Chile, work is currently underway on this topic and laws have been enacted (Dirección del Trabajo, n.d.), however -and due to contingency- this barrier has not yet been broken, because, as it is possible to notice, **teleworking** is not yet fully regulated at the country level. On the other hand, there are also barriers that cannot be solved with current technology, such as telemedicine, or the use of industrial robots (a kind of *actuator*). Currently, Chile does not have the technology to perform remote surgeries or other types of treatments, or carry out production processes -considerably at the country level- remotely, so tasks of this nature represent a limitation for **teleworking** despite the fact that the "State of the Art" indicates the contrary.

8.9 Summary of barriers at the national level

Table 14 summarizes the main barriers identified for the case of Chile, by integrating those that are particular for the national context, as well as those recognized and inherited from the international analysis.

An important transversal barrier to most sectors corresponds to the difficulty in setting up long-term innovation projects with non-immediate results and combining them with the political agenda (in the case of the public sector) and the needs of business (in the case of the private sector).

Table 14: Summary of barriers at national level

Class	Uses & applications	Summary of barriers
Smart grid	Smart substation	Economic incentives to implement this type of substation. National Energy Commission should include this technology in its transmission planning plans and in the technical normative. Lack of quantification of potential benefits. High investment cost (ICTs in particular)

Class	**Uses & applications**	**Summary of barriers**
		Information security.
	Feeder automation	Economic incentives to implement this type of substation by electricity distribution companies. Distribution added value should reward this type of investment. Lack of regulation that improves quality standards and supply security.
	Microgrids	Technical barriers (bidirectional power flow, stability, protection, coordination with centralized grids, safety) Lack of flexible regulation that permits bidirectional power flow, local energy trade. Lack of incentives to flexible resources.
DER management	Demand Side Management (DSM) / Demand Response (DR)	Lack of regulation so that residential and non-residential customers can participate in the wholesale energy market and ancillary services market. Enabling technologies (for example, smart meters) Maturity of smart appliances (smart lighting, smart heating, etc.). Connectivity and access to information. Security of the information.
	Energy storage	High investment cost. Lack of quantification of potential benefits. Regulation and participation on the market not fully defined. Conflict with displaced generators with long-term contracts.
	Virtual Power Plant (VPP)	Lack of regulation so that residential and non-residential customers can participate as VPP in the wholesale energy market and ancillary services market. Enabling technologies Connectivity and computational cost
	Distributed energy (electricity/DG & gas)	Regulatory barriers, customers participate as generators: the way in which they are priced and their market share must be adjusted. Need to upgrade the electrical system in view of a bidirectional flow. Security of the information.
Customer domain	Prosumer & P2P trades	Lack of infrastructure to measure and trace energy. Reduced types of energy product that prosumers can sell (energy only).
	Retailing, billing & customer orientation	Lack of regulatory framework for the retailer and aggregator. Lack of infrastructure to measure and trace energy. No market competition assurance in the new legislation project.
Process management	Process optimization & automation (gas, oil & coal)	High cost of modernizing processes Employee resistance to automation Support infrastructure required for wide-scale implementation Difficult to reuse models for different problems
	Emission monitoring	Economic incentives for large pollutant emitters High cost of modernizing monitoring systems
Mobility	Transportation for personal use	With regard to vehicle connectivity: Low market penetration of connectivity devices for vehicles; Lack of consensus on the technology to be massively adopted by vehicle manufacturers:

Class	Uses & applications	Summary of barriers
		Competition between IEEE 802.11 and 4G / 5G, Lack of regulation that requires the mandatory incorporation of connectivity in vehicles to enable the use of road safety applications based on vehicle-to-vehicle High investment cost for electric vehicles Prohibition for car conversion to electric Sizing of the facilities required at the residential level.
	Public transport	High investment in infrastructure Lack of incentives to prefer public transport over private
	Transport cargo	Lack of ICT skills in freight companies
	Shared mobility	Lack of regulation Private shared cars: High investment in vehicles. Lack of users to make the business profitable. High rates for use. Lack of parking places for share mobility. Carpooling: Travel safety Health security Shared mobility of different mode of transport: Payment system interoperability Shared bicycle, scooter: Security Issues for Business Owners
Data management	Predictive maintenance	Support infrastructure required for wide-scale implementation Lack of useable data Labelling data, can be an exceedingly expensive effort Inability to read and process unstructured data. Difficult to reuse models for different problems Unrealistic expectations of technology Lack of trust, knowledge and understanding of potential benefits
	Forecasting and predictive analytics	Incentives for electrical system operators Infrastructure for obtaining data and disposing of historical data Labelling data, can be an exceedingly expensive effort Difficult to reuse models for different problems Unrealistic expectations of technology Lack of trust, knowledge and understanding of potential benefits
Smart city	Smart lighting	Lack of knowledge of technology and reliability of suppliers High investment cost. Lack of economic incentives to implement this solution. Cybersecurity (for public smart lighting) Lack of a common data model for existing applications and systems within buildings and infrastructure, which impedes interoperability and limits the scalability of systems Low level of development of the ESCO model Absence of standards to avoid being tied to a single supplier. Certification program to accompany these standards to create full confidence in interoperability (These programs should be conducted

Class	Uses & applications	Summary of barriers
		by independent test centers and the certification status of products should be verifiable through a publicly accessible database and logos, with the trademark to avoid misuse).
	Smart traffic	Requires telecommunications infrastructure and fleet renewal for greater penetration. Difficulty in hiring new specialized personnel, increasingly necessary for the management of the digital transformation projects Lack of capacity to analyze large amounts of data and integration of platforms Absence of sustainable management models, capable of responding to the current challenges of the urban environment.
	Smart home & building	Cybersecurity and sovereignty of information High costs and unclear benefits to consumers Low consumer awareness Lack of interest Long replacement cycles Mistrust of technology Lack of trust in energy providers (for demand response enabled devices) Lack of standards and communication protocols that enable devices from different manufacturers to interact Insufficient product support services Absence of enabling technology e.g. load control devices.
	Smart industry	Lack of knowledge of technology Transition with significant investments in equipment and training New regulatory approaches Low level of development of the ESCO model Lack of sufficient financial incentives Failure to fully account for benefits. Lack of standardized measurement and verification. Lack of widespread adoption of interoperability and open standards.
	Smart farm	Major capital expenditure Internet access in rural communities Data protection and data sovereignty Familiarization with technology Low level of development of the ESCO model Incompatibility between different software and/or hardware products
	Smart parking	Investment cost for real-time information system Cybersecurity Municipal contracts not considering technological requirements Transition with significant investments in equipment and training
	Smart waste management	Training of citizens - behavioral changes Investment for infrastructure and computational cost. Incentives to companies for investment Lack of regulatory pressures Lack of market pressures and demands.
	Smart fleet management	Investment cost in infrastructure

Class	Uses & applications	Summary of barriers
		Cybersecurity and information sovereignty Vehicles with maintenance problems Fuel subsidy
Other	Market management & operation	Regulatory obstacles to new agents and ancillary services Lack of incentives to share electricity data
	Ancillary services	Need of a higher computational capacity for the implementation of new technologies (such as forecasting) in the ancillary services market.
	Energy management	Investment costs and disadvantageous comparison with other projects with better returns on capital Short payback requirements Lack of economic incentives to implement these solutions. Lack of regulation and governmental support to promote the implementation of energy management systems (for example, energy efficiency law is still to be implemented) Lack of energy-management codes or standards. Low level of development of the ESCO model Lack of in-house technical expertise Difficulty measuring and verifying energy and cost savings Ignorance of incentives and opportunities
	Operation (monitoring/control/reporting)	Conflicts with privacy due to the use of user information (customers with EV or who participate in the DR) Distrust towards smart meters
	Teleworking	Ambiguity between personal space and workspace can cause discomfort and reduce productivity Need for connectivity improvements at the residential level, access to remote information and lack of employee training. Costs to enable the conditions for a good performance (in the company and in the homes).

8.10 Analysis of three national actors

In this section, an analysis of opportunities was carried out for two public institutions linked to the energy sector that could benefit from the digital uses and applications identified in Chapter 1. The two institutions selected are the National Electric Coordinator (NEC or "Coordinador" as it is known in Chile) and the Superintendence of Electricity and Fuel (SEF o SEC as it is known in Chile). These institutions were subject to interviews where delegates discussed digitalization barriers and opportunities, presented below along with a preliminary analysis of opportunities based on the international and national review.

In addition, the private company Phineal was added to the interviewed actors, due to their recent relevant developments in digitalization technologies akin to the project.

8.10.1 National Electric Coordinator

The NEC is an independent institution responsible for coordinating the operation of the National Electricity System, preserving the electricity supply with the required security, economically and guaranteeing open access to transmission systems. In addition, it is the institution in charge to operate the energy and ancillary service markets. Currently, NEC has implemented several digital applications to comply with their functions which are described below (diagnosis made by consultant):

- Use of SCADA system to monitor system operation
- Automatic Generation Control (AGC) for frequency control (Note: currently there are countries that still do secondary control manually)
- Use Operation coordination models such as PLEXOS, PCP, PLP (prior to using these models, programming is performed using manual algorithms), parallelization of operation programming models (PLP model)
- Wind and solar resource projection models
- Water resource projection model
- Website so that coordinated companies can make their offers of complementary services
- Web page with report of the operation and indicators
- App with report indicators: hourly marginal costs, hourly generation, etc.
- Definition of Cybersecurity standards
- Use of two pilot programs for Blockchain

Table 15 shows identified new opportunities for the NEC. Some of these digital applications could affect indirectly to the Coordinator. For example, the NEC doesn´t do the investment in equipment or transmission lines of the power system, however, this kind of technology could be included in the transmission planning proposal which every year is done by the NEC. DERs applications can participate of wholesale energy market and ancillary service market. Again, NEC doesn´t invest in this kind of technology, however, in the Ancillary Service Report, NEC must determine the technical need to include the DER as an ancillary service.

Table 15: Potential opportunities for the National Electric Coordinator

Class	Uses & applications	Description of opportunities
Smart grid	Smart substation (indirect)	Incorporation of substations in transmission planning proposal by the NEC.
DER management	DSM/ DR (indirect)	Incorporation of DSM to wholesale energy market and ancillary service market.
	Energy storage (indirect)	Incorporation of DSM to wholesale energy market and ancillary service market. Incorporation of storages system in the transmission planning proposal.
	Virtual Power Plant (indirect)	Incorporation of DSM to wholesale energy market and ancillary service market.

Class	Uses & applications	Description of opportunities
	Distributed energy (electricity/DG & gas) (indirect)	Digital application to monitoring distributed power plants. Currently the online monitoring of distributed energy source is not possible.
Customer domain	Prosumer & P2P trades (direct)	Currently, the coordinator is carrying out a pilot program with blockchain technology for the certification of cost statements and fuel stocks that are used in the daily operation scheduling. This application could be extended for other types of information that the coordinated companies must declare.
Process management	Process optimization & automation (direct)	Use of Big Data applications to capture, store and process large amounts of data associated with the operation of the system and the operation of the market. Use of Business Intelligence application to automate calculated processes carried out periodically, for example, energy transfer balance, capacity payments balance, real marginal cost, etc. Use of Robotic Process Automation to repetitive activities.
Data management	Predictive maintenance (indirect)	To promote predictive maintenance of power plants and transmission lines (use off smart sensors, machine learning, etc. enabling technologies)
	Forecasting and predictive analytics	Use of Machine learning, Deep learning, IA to monitor security of power system (currently Coordinador is developing a FONDEF with University of Chile), to project renewable resources, projection of electric demand, etc.
Other	Market management & operation	Currently these are the main functions of the NEC.
	Ancillary services	Currently this is a function of the NEC.
	Operation (monitoring/control/reporting)	Currently this is a function of the NEC.
	Information	Dissemination of information through the website and apps.

On the interview, the delegates from NEC recognized the importance of incorporating digital technologies not only in their work, but also in the work of the participants ("Coordinados"). As recognized in Table 15, uses such as those in the Data Management and DER Management classes are considered as part of the upcoming change in the electricity sector, with mentions of specific promising technologies such as Big data, machine learning & AI, but also Flexible AC Transmission System (FACTS) and Phasor Measurement Units (PMU). The latter is being currently addressed in a Fondef project jointly developed with the University of Chile.

The main barriers recognized by NEC come from the limitations in terms of time and resources. Although there is much enthusiasm for the opportunities that the digital technologies offer, the limited budget, exacerbated by the current pandemic situation, impose a big challenge. NEC has an active participation in the International Council on Large Electric Systems (CIGRE), particularly on study committees C1 and C2, where the digital transformation has been discussed for four years. They agree that a collaborative work with the participants is key for the overcoming of barriers.

The goals that NEC pursue are declared in their 2017 Strategic Plan, which will be updated by the end of 2020. In their current plan, the connection between the former Central Interconnected System (SIC) and the Northern Interconnected System (SING) was the main topic. Looking into the opportunities of the digital transformation, NEC recognizes opportunities in forecasting and predictive analysis tools, with applications to intraday trading, real-time dispatch and security-constrained unit commitment, all considered into the Market management and operation uses. These tools will make monitoring useful not only in post-operation analysis, but also for real time operation. Finally, adoption of distributed energy resources and the electrification of heat, e.g. by using combined heat and power (CHP), are also seen as an opportunity due to their interaction at the distribution and transmission levels.

8.10.2 *Superintendence of Electricity and Fuel*

The SEC is the institution in charge of supervising and supervising compliance with legal and regulatory provisions, and technical standards, on production, storage, transportation and distribution of liquid fuels, gas and electricity. Likewise, it must verify that the quality of the services provided to users is that indicated in the regulations and technical standards; and that the operations and use of energy resources do not constitute danger to people. Currently, SEC has implemented several digital applications to comply with their functions which are described below (diagnosis made by consultant):

- Computer platforms for information sharing with companies (example: supply quality distribution companies through STAR system)
- Georeferencing of electrical and fuel infrastructure
- Online reports (for example, customers without electricity supply)
- Web platform to enter claims, claims for supply cut
- Registration on the web platform of Electro-Dependent patients with Home Hospitalization
- Web Platform "Follow-up Action Plans"
- Mobile Application - Electrical Risk on public roads
- Installers License Request via Online
- Paperless Energy - Digitized Concessions
- Certification and Inspection Products, QR seal

Table 16 shows identified new opportunities for the SEC. As we above, also here some of these digital applications could affect indirectly to the SEC.

Table 16: Potential opportunities for the SEC

Class	Uses & applications	Definition / Description
Smart grid	Feeder automation (indirect)	Remote control of distribution equipment (feeders, etc.)
Process management	Process optimization & automation	Use of Big Data applications to capture, store and process large amounts of data Use of Business Intelligence to prepare reports and statistic reports. Use of robot to natural gas and oil inspections (indirect application).
Smart city	Smart lighting	Smart equipment regulation
	Smart home & building	Smart equipment regulation
Other	Market management & operation	Online detection of points of failure in the network

On the interview, the delegate from SEC recognized the benefits of digital technologies, in particular those related to Big Data, as SEC manages large amounts of information. Supervising and inspecting activities are also recognized, although some technological barriers exist, such as the necessity of continuous calibration of specialty sensors (e.g. gas).

There are several opportunities recognized from digital applications. On Data management, the validation and traceability of information, in particular data transactions, is stated as key. Nevertheless, once the information is available, its exploitation would need human capital that is educated in this respect.

8.10.3 *Phineal*

Phineal is a company founded in 2013, currently comprising three business divisions: Central, which works on solar photovoltaic systems deployment, including both on-grid and off-grid applications; Solar Robotics, focused on mobility and energy storage; and phiNet, the division of the company that focuses on monitoring and information platforms. The latter was the focus of the interview.

The name phiNet is used for the information platform developed by the company, focused on the performance measurement of photovoltaic plants. While the information platform has seen updates and newer versions have been developed, new platforms have also become part of phiNet, such as Sello Sol and GTIME. These last two are digital platforms for traceability using blockchain technology. While Sello Sol is developed for solar energy, GTIME is presented as a more general energy traceability system.

Their blockchain application traces energy through IoT devices, measured with a high resolution (as fast as every minute) and consolidated into an GTIME (geolocation, timestamp, ID, MAC address and energy measurement) vector. These are mined and published continuously. When combined with an energy marketplace, where consumers and producers can interact, energy transactions can be traced, certified and validated. This digital application has recently won the Blockchain in Energy Transformation Challenge, organized by GIZ's Mexican Energy Partnership and Siemens Energy Mexico (PV Magazine, 2020). Their blockchain application is currently being tested in a pilot developed by Transelec, where several solar photovoltaic plants are being traced.

Phineal recognizes that there are still many barriers for the development of digital solutions, such as data sovereignty, as data needs to be digitized, and data access granted in a secure way, in order to offer novel services. From the economic perspective, the cost of transmitting information and accessing Internet is something that they have had to face: while in other countries there are special tariffs for Machine-to-Machine (M2M) communications, there is no such thing in Chile yet. Phineal recognizes that a differentiated tariff for IoT devices is needed. In addition, in line with what was previously discussed about Process optimization and automation, some actors might go against digitalization fearing that jobs can be eliminated.

Despite the barriers, Phineal agrees on many opportunities that this project has detected. For example, technologies such as blockchain can be enablers of other digital applications. Phineal states that mobility applications, in particular electromobility, are catalysts for digitalization, as they rely on transactions that are facilitated by digital technologies.

9 Applications that benefit and involve citizens

In this section, a selection of digitalization uses that involve citizens is presented. For each use, the benefits that these digital applications bring to citizens is analyzed. Special attention is paid to those technologies and uses that could help connect people to the policies promoted by the Ministry of Energy.

9.1 Microgrids

The use of microgrids brings benefits to citizens in terms of reducing energy costs, reducing local pollution, improving reliability, security and quality. Given that distributed generation predominates in this type of network, the use of renewable energies takes on greater relevance, which implies lower energy costs and less use of conventional generation. On the other hand, the enabling technologies for this use also imply other benefits, the arrival of the IoT through Smart Sensors or Cloud services allows the operation of this use and can also be used for applications outside of microgrids, such as Smart Waste Management, Smart Farm, etc.

The Ruta de la Luz initiative constitutes one of the best-oriented policies in the implementation of this use, by bringing access to electricity in remote locations, not connected to the main grid. Policies like "Casa Solar" could eventually be harnessed for this use. Considering also that microgrids can be located in rural areas of the country, it also implies an increase in the well-being of the population by increasing accessibility to electricity, supplying electricity to areas where it was not possible to achieve a good shape. An example of this in the Chilean case is the Huatacondo microgrid, where some of the aforementioned benefits can be seen in evidence. In addition to the case of Huatacondo, another locality that is considered within the policies is the case of Rapa Nui, where this use becomes relevant and can generate great benefits to the inhabitants of the island through the development of microgrids as an alternative of sustainable and community energy solution.

9.2 Demand Side Management (DSM)/ Demand Response (DR)

This use is intrinsically related to citizenship, understanding that its implementation not only entails direct benefits for the population (such as lower emissions, contribution to energy efficiency or cost reduction due to efficient consumption management), but also requires the active participation of energy consumers so that its implementation is successful and that its effects are greater.

Policies associated with the liberation of the electricity market encourage the participation of end users and promote the diversification of services. In our country, the so-called distribution reform considers 3 bills in order to modernize the distribution sector, in order to better face the challenges of the electrical networks of the future. In particular, the recently published Electric Portability Bill will open up competition in the distribution sector and provide flexibility to the system, by separating the commercialization of the operator from the distribution networks, treating it as an independent agent, in addition to adding a new agent that manages the information collected from the network. This will encourage the creation of deferred rates according to the needs of each user, and even rates considered by DSM/DR may be established. The latter is incorporated into what is expected to be the third Reform Bill, that of Distributed Generation, which will explicitly define new actors (such as the demand aggregator) and create the regulatory framework for the integration of new products and services.

9.3 Energy Storage

Large-scale Energy Storage allows you to take full advantage of generation based on renewable resources, reducing the price of energy and GHI emissions by stopping generating with thermal units. This constitutes an indirect effect for citizens. However, on a small scale, if this use is complemented with a DSM / DR mechanism, its effects on citizens are even more evident. For example, if a person has energy storage equipment, they could arbitrage with it, in order to charge the equipment when the price of energy is low and later consume it when the price rises, in addition to contributing to the security of the grid.

For this, it is vital to incorporate tariff mechanisms that are capable of perceiving changes in the price of energy with hourly resolution. In this sense, the reform discussed in the previous point also proposes a change in the rate systems, which each user will be free to choose according to their needs and preferences, being able to change the rate or marketer in case of wanting to opt for a different option.

9.4 Distributed Energy (Electricity/DG & Gas)

Distributed energy brings economic benefits to citizens, reducing the amount of energy consumed from the grid and even receiving income for injecting energy into it. It also implies improvements in the security of supply thanks to the support it provides to the network, also providing greater independence. Furthermore, considering that in general terms the DG considers renewable resources as a source of generation, a decrease in GHI emissions is observed. Finally, in the event of supply cuts associated with failures in the distribution system, it allows those users who have DG in their facilities not to perceive a load disconnection.

Policies that encourage the purchase of the equipment necessary for the installation of DG at lower prices promote the massive adoption of this use by citizens. In this sense, there are already programs at the national level that are oriented towards the aforementioned objective.

"Casa Solar", a program funded by the Ministry of Energy and executed by the Energy Sustainability Agency, allows the aggregate purchase of residential photovoltaic systems by individuals whose houses are connected to the distribution network, in order to take advantage of values wholesalers for the unit acquisition of solar photovoltaic systems of 1 [kWp] or 2 [kWp], and depending on the tax assessment of the applicant's home, a state co-financing of up to 50% could be counted on for the purchase. The executing company will create groups of at least 100 beneficiary homes in geographically close areas, which must go through stages of studies and field visits, hoping that a minimum of 50 homes can be put out to tender. As mentioned in section A), the program coverage territory is for territorial and insular Chile.

9.5 Prosumer & Peer-to-Peer (P2P) Trades

The benefits for citizenship set forth in the previous subsection also apply in the case of prosumers. Therefore, the policies promoted by GD also favor the penetration of this use, considering that it enables the installation of the necessary equipment so that end users become active agents of the network when generating energy. Although the policy just commented complements the implementation of this use, it requires a regulation that makes it possible to obtain economic benefits through the injection of energy into the grid. In this sense, the "Distributed Generation Regulation for self-consumption", known as the "Netbilling Regulation", establishes the conditions and procedures required for a complete implementation of the generation equipment, as well as defining the limits allowed for connection and injections and, finally determines the necessary measurements and the valuation of the injections and transfers of surplus energy. In other words, said regulation enables the existence of the prosumer as an agent in our electrical system.

On the other hand, the benefits that P2P brings to the systems for implementing mechanisms are related to the level of consumer participation, enhancing and generating greater involvement with the energy market, without the need for external agents. In that sense, the concept of cryptocurrency powers this type of exchange. Unfortunately, even when the concept of cryptocurrency has been incorporated in some studies carried out, the purpose of which is to nurture the development of public policies and government strategies in pursuit of a modernization of different sectors (for example, the Blockchain document in (Ministerio de Economía, 2019)), there is still no clear statement in this regard.

9.6 Retailing, Billing & Customer Orientation

The benefits associated with these are related to the promotion of citizen participation in the energy market and the improvement in the quality of service due to an increase in the transparency of the information, promoting a better experience for the end user. In this sense, all the policies that protect the end user and that establish the obligations that ele.ctricity companies must follow will contribute to the application of these uses. For example, within the same reform and bill mentioned in section B), the creation of an agent is included that guarantees equitable access to information (reduce asymmetries) and data protection. The foregoing is in addition to the already existing policies that establish the obligation on the part of companies not to make mistakes in billing and to deliver good customer service, as well as define the agents responsible for monitoring good performance.

9.7 Transportation for Personal Use

The incorporation of digital technologies in the transport sector allows the creation of ad hoc vehicle networks, and the collection and management of information helping to optimize traffic. This implies a reduction in transportation times, which in turn implies an increase in the welfare of the population by having a vehicle system that generates less stress. On the other hand, the improvements in traffic that would be achieved collaborate with the reduction of emissions, also considering that this use is linked to EVs as both are emerging technologies in the field of mobility.

It is important to note that there are no explicit policies on digital technologies in transportation for personal use, however, there are electromobility policies related to this use, such as the "National Electromobility Strategy" which considers the "Promotion of research and development in human capital", mentioning the importance in the maintenance and operation of the cargo network and the strategic challenges where this use may be relevant. On the other hand, the importance of having information systematized, updated and adapted to the local case (as part of the "Transfer of knowledge and delivery of information") is also highlighted, where this use can also become relevant.

9.8 Public Transport

Similar to the case of vehicles for private use, it facilitates connectivity between vehicles, or connectivity between users and vehicles. This generates a reduction in emissions thanks to the optimization in the use of fleets (example: use fewer subway cars if little flow of people is detected). On the other hand, there is also an increase in the welfare of the population by having a more intelligent public transport system. Faced with an eventual interaction between the user and the network, it could be detected when the number of buses on a certain route does not have the appropriate number of vehicles, or through the exchange of information thanks to the networks of public transport vehicles, routes can be recommended to users who decongest the system.

Advances in this use can be driven by the electromobility agenda, where it is expected that by 2040 there will be 100% electric public transport. Although this is not directly related to this use, the updating of the fleet implies, in addition to its electrification, the inclusion of new technologies that can promote this use. On the other hand, interaction with the network of public transport vehicles is already possible through mobile applications implemented by the government, so that -in seeking to improve these services- this use can be promoted.

9.9 Shared Mobility

This use generates benefits both in costs, as in reducing emissions and transport time. Given that it involves vehicles that do not use fossil fuels, its associated emissions are reduced, on the other hand, by not needing private vehicles, charging costs (with fuel or electricity) and investments are no longer incurred, which means savings for citizens. On the other hand, given that this use generates greater accessibility to means of transport, it will reduce the transport times of users who take advantage of this use.

In Chile, shared mobility has gained strength in recent years with applications such as "All Ride" that is complemented by the use of social networks such as Facebook or LinkedIn, generating other types of benefits unrelated to mobility, associated with obtaining information from users in case they give their consent, and generate new instances of social interaction. Applications such as MoBike, or Bike Santiago, in addition to the shared use of scooters, also show that it is a use with potential in the country, but in which progress must also be made on issues of policies and regulations as established by Minister Gloria Hutt.

9.10 Energy Management

The information management that allows the use of Energy Management is complemented by other uses such as DR / DSM, which generates the benefit of reducing energy costs if it participates in demand management. On the other hand, the local control of ventilation devices, light or other types of devices provides an increase in the well-being of citizens by adjusting automatically according to user preferences. This participation in the management of demand and control of the devices implies a closer to optimal operation by the system, which could even reduce supply interruptions.

On the other hand, the devices used for Energy Management are linked to the IoT, so that together with this use, users could receive other types of benefits unrelated to energy consumption, such as the automation of bill payments. Currently there are no explicit policies in the country on Energy Management, however this use can be linked to energy efficiency policies, where this use can collaborate in promoting energy efficient equipment in the market for the residential, commercial and public sector, or contribute so that new buildings have OCDE standards for efficient construction, through an energy control and management system.

9.11Teleworking

Teleworking clearly involves citizens and its growth has been accelerated by the COVID-19 pandemic all over the world, Chile is not an exception.

It is often said that teleworking brings benefits for both the employer and employee. On the employer side, reduction in real state costs and increasing in productivity are the main advantages. For the employee, the time flexibility, the conciliation between family and professional life, and reduction in personal costs are potential benefits. But there is evidence that shows that teleworking can result in longer working hours and professional isolation.

The recent legislation in Chile tries to address this risk by establishing a "disconnection right" that free employees of answering employers' requirements for a period of 12 hours. Even though this seems like a good way to protect the employee from long working hours, the same legislation also let the teleworker to be exclude of the legal maximum working hours if there is an agreement between both parts, thus exposing teleworkers to longer workdays.

9.12 Smart Lighting

Smart lighting, especially public smart lighting, can improve safety, reduce energy cost, and equipped with multiple sensors serves as great source for data in the smart city context, improving citizens overall wellbeing.

In Chile the Corporation of Production Fostering (CORFO in Spanish) implement the "Enabling Infrastructure for Smart Cities" program, which run a pilot smart lighting system and developed a technical guide for municipalities to replicate the experience.

By December 21st of 2018, at least 5 municipalities had announced or implemented smart lighting plans, Calbuco, Las Condes, Providencia, Puente Alto and La Reina.

9.13 Smart Traffic

This use involves citizens in their daily living. The main benefits are the reduction of energy cost for transportation, the reduction of GHG emissions by decreasing traffic time, and improvement in the life quality of citizens by better dispose of their time, not only because of less trip time, but also because of more information regarding traffic state, routing, and public transport scheduling.

In Chile, the Coordination of Intelligent Transport Systems (SIT) was born in April 2019 with the purpose of transforming the planning and management of people's mobility, improving their travel experience.

SIT focuses on mass transportation and sustainable modes, for the equitable use of public space, improvement of security and through the comprehensive management of traffic (vehicular, cycles and pedestrians), information to users, and availability of data for travel planning platforms.

Its work includes the intensive use of data & analytics and ITS (intelligent transport systems) solutions, leveraging the transport ecosystem.

9.14 Smart Home & Building

Smart home technology provides homeowners security, comfort, convenience and energy efficiency by allowing them to control smart devices, often by a smart home app on their smartphone or other networked device. A part of the internet of things (IoT), smart home systems and devices often operate together, sharing consumer usage data among themselves and automating actions based on the homeowners' preferences. While every smart home is a smart building, not every smart building is a smart home. Enterprise, commercial, industrial and residential buildings of all shapes and sizes are deploying IoT technologies to improve building efficiency, reduce energy costs and environmental impact, and ensure security, as well as improve occupant satisfaction.

In the energy policy document "Energía 2050" published in 2015, energy efficiency is a main topic and establish targets for long- and medium-term regarding public, residential and commercial building, those targets could be achieved by implementing smart home and smart building technologies.

9.15 Smart Farm

Smart Farming represents the application of modern Information and Communication Technologies (ICT) into agriculture upon the combined application of solutions such as precision equipment, the Internet of Things (IoT), sensors and actuators, geo-positioning systems, Big Data, etc. Smart Farming should provide the farmer with added value in the form of better decision making or more efficient exploitation operations and management. Achieve better efficiency and improve decision making can bring great benefit to society in a country like Chile were the agricultural sector accounts for approximately 3% of the total GDP, and reach over 10% of local GDP in the regions O'Higgins, Maule and Los Ríos.

CORFO launched in 2019; for the region Maule, O'Higgins and Ñuble; the program "SMARTFUIT: Digitization of Fruit Agri-food Chains" to support the development of enabling technologies, which are the engine of the digitization of the fruit industry, focusing on its production chain. Other objective of the program is to develop and promote the adoption and use of open and safe standards for interoperability, which enhance the productive process of the fruit industry, promoting efficient practices through standardized and interoperable solutions. This program includes a fund for up to 3,000,000,000 Chilean pesos for the company or organization that get selected.

9.16 Smart Parking

As a result of using Smart Parking, citizens who are looking to find a parking spot will find it in the most efficient way possible and companies or municipalities can optimize their parking territories. It also makes cities more livable, safer and less congested.

In Chile, some startups are already operating such as ParkingAPP, SafeCard and WesmartPark. This last one, WesmartPark, have an agreement signed with the municipality of Las Condes, which give the citizens of this zone preferent prices in the parking spots available in the application.

Some experts indicate that despite the fact that there are a large number of ventures and innovations that are trying to reach the market, the large private concessionaires and private car parks sign contracts with the municipalities that do not favor the incorporation of third parties and these contracts do not require this type of technology to be included in their services, which makes them insensitive in economic terms.

9.17 Smart Waste Management

All citizens produce municipal solid waste on a daily basis, due to recent population growth and urbanization, waste production in cities has increased, and municipal waste collection operations need to adapt to be able to ensure clean cities. Smart waste management solutions use sensors placed in waste receptacles to measure fill levels and to notify city collection services when bins are ready to be emptied. Over time, historical data collected by sensors can be used to identify fill patterns, optimize driver routes and schedules, and reduce operational costs. Some other benefits that this IoT solutions can give to citizens are; improve street sanitation, encourage recycling, and increase Wi-Fi coverage with their function as a free public Wi-Fi hotspot.

Within the context of the Neighborhood Revitalization Program and Emblematic Heritage Infrastructure (PRBIPE) of the Undersecretariat of Regional and Administrative Development (Subdere), the Municipality of Estación Central inaugurated, in October 2020, a system of intelligent compactors with the aim of managing urban waste in high traffic points of the commune. This system is the first of its kind in Chile, and operates a network of 40 smart containers that are powered by solar energy. The project, which will have an investment amount of $ 190,147,125 Chilean pesos, will benefit more than 44 thousand residents of Estación Central.

10 Contributions to future policies that promote digitalization at the national level

This final section provides an analysis of the public policies relevant to energy that could facilitate the detected potentials and avoid potential risks, in order to avoid important gaps in the penetration of information technologies and in the digitization of the energy sector in general. For this task, the gaps and opportunities detected in the review of international and national experience are reviewed.

As we discussed in previous sections, digitalization is an important instrument for the energy transition and an enabler of two key industry trends: decarbonization and decentralization, both critical to enabling the energy transition.

In this sense, digitalization strategies at the international level are strongly promoted by the public sector and are developed with a national focus and considering the different sectors and areas that could benefit, not restricting the analysis to the energy sector. For example, reviewed policies cover issues of education, health, safety, public service, city, etc. The foregoing shows that the promotion of digitization at the national level cannot be seen not only from the energy sector point of view, but requires the articulation of different public bodies in charge of promoting this type of policies, which includes, for example, the Ministry of Energy, Ministry of Transport and Telecommunications, Ministry of Housing and Urbanism, Ministry of Finance, Intendants, Regional Governors, mayors, etc.

At a general level, although our country has good conditions related to the coverage and access to mobile Internet, technological and infrastructure capacities, among others; there are still limitations in these aspects, which do not allow certain technological uses and applications to enter into a level of maturity similar to that of developed countries, such as those reviewed in this study.

In aspects such as regulations, standards, certifications, access to economic resources (or economic incentives), information security and sovereignty, among others; the gap with developed countries and with an expected level of development at the national level is even greater.

Considering the international experiences, the following policies are recommended to reduce barrier and promote the implementation of uses and digital applications:

- Promote articulation between the different institutions related to the digitization of the different sectors at the national level, considering a national policy approach.
- Promote and disseminate the existence of identified digital applications to the public and private sectors.
- Include the impact of the digitization of the energy sector in long-term energy policy and in climate change mitigation policies.
- Policies to increase the public investments in digital infrastructure, build a large-sale ICT infrastructure that supports public utilities and other service such as road infrastructure. This includes the massification of 5G and AI technology.
- The adoption of a common data architecture, tools, and standards to reduce bugs and raise the quality, reliability, and security of devices and services, and that facilitates economies of scale and data sharing across different institutions. Given the large number of technologies available to enable the IoT platform underlining many of the Smart services, it is instrumental that the architecture ensures interoperability, for example by establishing an IP-

based model with standard protocols for communications such as UDP, CoAP, HTTP, etc., regardless the data that is transported through the network.

- Reduce the digital gap among the different territories of the country (NIC Chile, 2018). Many future services will require the latest generation of mobile and fixed Internet access technologies (e.g., 4G, 5G, and fiber optics) to transport the large amount of data coming from the digitalization processes. If such technologies are available only to a restricted number of cities or regions, the benefits and possibly the operative margins for innovative services may not be achieved, since large portions of the population will not have the technological means to access to such services (even if they afford to pay for them).
- Policies to increase investment in human resources and education related to digital application and enabling technologies. This includes the primary school, secondary school, technical and university educations.
- The implementation and reinforcement of Government's Personal Data Protection Laws and Policies for public and private sectors.
- The development of pilot programs to promote the use of different digital applications, involving the public, private sector, and academia sector may reduce the barriers of entry of different technologies.
- Policies to encourage investment by private parties in projects associated with the digitization of the energy sector (greater offer of shared mobility, aggregators for VPPs, smart lighting services, etc.)

10.1Electricity generation

Currently, is under discussion a project law to introduce competition into the electricity retail market for small and medium customers via the figures of the electricity retailer and the information manager, in order to separate the distribution grid operation (concerning the distribution company) from the commercial operation (which would concern the retailers).

In this near-future scenario, it is expected that digitalization enables an active participation from end users, both residential and non-residential, in all electricity markets. With greater adoption of Distributed Energy Resources and connected devices, retailers could give more relevance to Virtual Power Plants and Demand Side Management as new resources for network control and energy services.

Greater electrification will be one tool to achieving net-zero carbon targets for buildings and manufacturing in countries such as Chile, where an increasing number of technical solutions are becoming available. This greater electrical demand from energy users, combined with growing variable generation from renewables, creates opportunities to provide greater value to power markets through demand-side management, allowing businesses or aggregators to be rewarded for being flexible with their use of electricity by shifting or reducing demand, or by making capacity available through onsite generation, when needed. For this to be a reality, the definition of standards and regulation reforms for the electricity markets become necessary in the short/medium term in order to allocate the right incentives and ensure interoperability for this type of services and technologies. The promotion of enabling infrastructure such as the roll-out of smart meters and incorporating bidirectional communications to the smart grid will also be key to the transition to happen.

10.2 Transportation

At the transportation level it is important to advance regulations associated with interoperability, privacy, and safety, standards for vehicle conversion and incentives to promote the use of public transportation and low emission vehicles. Furthermore, from an economic point of view, it is important to review the economic incentives in the regulatory framework, to not generate regressive effects on the sector, such as the promotion of individual fossil fuel vehicles over less polluting type of transportation. Economic barriers associated with the use of digital applications in public transport in regions and their impact on transport rates need to be solved. Also, continuing to improve the collection and management of information at the urban and interurban levels, especially in regions, will allow progress to be made toward modernization (associated with the digital transformation) of the sector. In the case of freight transport, the fact that it is a fairly atomized market, it is necessary to spread digital technologies in this segment.

10.3 Industry

At the industry level, the main barriers to drive energy efficiency faster, taking advantage of digital technologies, have to do with the lack of regulation, low capacity of human capital (own and ESCOs) and incentives defined by the owners of the companies regarding the benefits that digitalization can bring in terms of energy savings and other types of efficiencies. In the latter case, to the extent that investments in the industry are evaluated with short-term metrics (for example, capital recovery or payback) without incorporating incentives to promote clean technologies or other sustainability related metrics, technologies associated with digitalization will not be useful tools in this regard. In this sense, the poor availability of information that generally exists in the industry is a major barrier to improving the sector's energy performance, and digital applications are a key element in overcoming this barrier.

In fact, much of the energy use in large buildings and in industry is administered using energy management systems and controls. Using more sophisticated digital tools, data analytics and visualization software will drive even better management. This includes replacing traditional metering with smart meter technology that is combined with machine learning capabilities, to enable organizations to analyze, understand and predict their energy use. For this transition to smart meters, it must be analyzed how to address the social barrier that recently originated towards this enabling technology, as it can slow down progress in this sector even with regulatory and capital barriers.

The Energy Efficiency Law currently under discussion establishes the obligation to introduce energy management systems within companies. This could trigger the development of digital technologies such as the automation of processes and the use of technologies associated with smart industry and smart transport.

10.4 Buildings

In the same way as in industry, at the buildings level, the poor quality of information on energy consumption and generation is a major barrier to the efficient energy performance of this sector. In this sense, digital applications could be key to overcome this barrier. However, poor regulation, low consumer confidence, lack of standards and communication protocols, and low confidence in technology providers, among others, are key barriers that need to be addressed in order to make progress in improving this sector. In this sense, it is important to take advantage of the opportunities provided by the distributed generation law and the penetration of renewable.

Similarly, to industry, IoT, Big data analytics, Data Visualization and Automation are also critical to support energy efficiency. Today's energy efficiency at industry and buildings have access to vast amounts of customer and product data. This data can be utilized and analyzed with increasing granularity opening up a range of services and solutions to help customers act. The challenge comes in supporting energy users to access this data.

In summary, the impact of digitalization will be over the whole life cycle of a project from development to construction and operations allowing to improve business efficiency, reduce costs and create new products and services

10.5 Public sector

In the case of the public sector, the diagnosis is similar to that of industry and buildings, in terms of information and problems with regulations, standards, protocols and technical capacities. However, given the exemplary role that the public sector should have, this requires that this type of application be developed with greater drive in this sector, which is in contrast to the bureaucracy that governs it.

Then, the possibility that public institutions can generate and sell part of their energy safely using blockchain or a digital marketplace, gives a high level of transparency and cybersecurity to these initiatives. This goes hand in hand with the standards that the State will require to venture these processes more frequently, as seen in international experience.

In this sense, experiences such as public PV roofs, initiatives developed through ESCOs, among others, should be a guide for digitalization applications to improve the sector's performance.

10.6 Finance

For the finance industry, digitalization can bring new opportunities and improved business models. However, hurdles such as traditional market environments, frameworks which can't be adapted to changing technology, new market mechanisms such as power purchase agreements and varying degrees of technology maturity, is holding back the tide of progress.

The greater availability of renewable energies, together with the greater security of supply that digital applications can provide, generate an important opportunity for the financial sector, particularly banks, to offer more friendly products with these technologies, reducing the risk and cost of financing for these projects.

The financial bankability of projects that have better economic performance, more facilities for payment of services or greater reliability with respect to their information (historical and online), should be greater and with better performance.

In this sense, advances in interoperability of means of payment and standardization in the electromobility sector, intelligent networks, among others, can encourage greater penetration of these technologies, with the consequent reductions in costs, emissions and associated risks.

Also, the development of technologies such as IoT, Big Data and blockchain can improve the performance of uses such as renewable certification, "X as a Service", Prosumer & P2P trades, Smart home and building, Smart city, amo7ng others.

10.7 Summary of current policy state and recommendations

Table 17 presents a summary, by sector, of current policy, policy under discussion or in progress, as well as recommendations for future policies regarding digital applications and technologies.

Table 17: Summary of current state and recommendation

Sector	Current regulation	Regulation/Bill in process	Recommendation
All/Personal Data Protection	▪ Law 19628 (On protection of private life)	▪	▪ The implementation and reinforcement of Government's Personal Data Protection Laws and Policies considering the use of data related to digital applications.
All/Security of Information	▪ National Policy of Cybersecurity 2017-2022 ▪ Cybersecurity standard (National Coordinator) ▪ Technical standard of quality of service for systems distribution (Define the use of ISO 27.001 Standard - Security Management of the information)	National Cybersecurity Policy	Regulation to implement cybersecurity standard
All/Digital gap	▪ General Telecommunications Law (Law 18168)	▪ 5G public tender	▪ Regulation to reduce the digital gap among the different territories of the country. Modification of the General Telecommunications Law to generate market incentives to guarantee the quality, coverage and resilience that we need (NIC Chile, 2018). ▪ For example, coverage requirements during bidding processes of networks.

Sector	Current regulation	Regulation/Bill in process	Recommendation
All/Education	▪ Law 20.910 that creates 15 State Technical Training Centers (CFT) throughout the country, in order to strengthen the quality of Higher Level Technical Education ▪ Development of ChileValora's National Registry which contains detailed information on certified job profiles (associated with energy and other sectors).	▪	▪ Regulation to promote education related to digital application and enabling technologies in primary school, secondary school, technical and university educations (For example, climate change issues were included in the curriculum of basic and secondary education).
Electricity generation	▪ Regulations that allow the participation of the demand in specific ancillary services (Decree 113) ▪ Technical Standard of quality of service for systems distribution (year 2025 as deadline to implement smart meters). ▪ Technical annex measurement systems, monitoring and control ▪ Minimum Design Requirements for Transmission Facilities (specifications on smart substation)	▪ Electricity retailer law ▪ Flexibility strategy ▪ Climate Change Law[20]	▪ Definition of standards ▪ The promotion of enabling infrastructure such as the roll-out of smart meter ▪ Incorporating bidirectional communications ▪ Regulatory incentives for the development of smart grids ▪
Transport	▪ National Electromobility Strategy ▪ Labor flexibility Law 21220 (which affect teleworking)	▪ Climate Chante Law ▪ Efficiency Energy Law[21]	▪ Regulation to promote sustainable transport (For example, Law of Mobility Orientation described in this document wishes to give priority to sustainable transport: development of infrastructure for non-motorized transport, encourage the use of new mobility solutions (carpooling, cycling, and other shared mobility), stop sale of fossil fuel vehicles, development of multimodal transport platforms, etc.

[20] This law could help promote the introduction of measures that help reduce greenhouse gas emissions for all sectors.
[21] This law could help to promote efficiency measures, energy management systems, etc.

Sector	Current regulation	Regulation/Bill in process	Recommendation
			▪ Advance regulations associated with interoperability and standards for vehicle conversion and incentives to promote the use of public transportation and low emission vehicles. ▪ Define a common standard to communication systems between vehicles ▪ Pushing the timely adoption of wireless technologies such as 5G, IEEE 802.11p, and other for IoT. The high-throughput/low-delay connectivity is critical for the deployment of many digital applications in this sector. ▪ Standard requirements for imported vehicles to incorporate communication systems. ▪ Regulation for autonomous vehicles (For example, legal framework that supports the operation of private transportation, including civil and penal responsibilities)
Industry, Residential, Commercial	▪ Labor flexibility Law 21220	▪ Climate Change Law ▪ Efficiency Energy Law ▪ National Policy on Artificial Intelligence	▪ Advance regulations associated with interoperability and standards ▪ Revision of the flexibility law in the context of the digitization of industry and commerce ▪ Regulation to the development of pilot programs ▪ Regulation associated with the use of artificial intelligence[22]. ▪ Campaign to promote services such as "X as a service", smart buildings, etc. to show their environmental, social and economic benefits. ▪ Development of regulations associated with circular economy and energy efficiency at a residential level to

[22] See for example https://obtienearchivo.bcn.cl/obtienearchivo?id=repositorio/10221/26982/1/Politicas_Publicas_para_la_Robotica_y_la_Inteligencia_Artificial.pdf

Sector	Current regulation	Regulation/Bill in process	Recommendation
			promote the use of these technologies in the sector.

Conclusions

This report presented a state-of-the-art review of the digital revolution, with a focus on the energy sector and other associated sectors, as well as an analysis of gaps, goals, barriers and opportunities for several digitalization applications. The review included scientific publications as well as policy from key countries that were selected for their merits in an international digitalization ranking. The analysis included the international experience that allowed the recognition of barriers and opportunities at the national level.

A total of 30 key uses/applications were identified from the literature review, along with eight classes that group related applications. Several enabling technologies have also been identified, divided in six categories. From the analysis, smart grid technologies and uses are prevalent. Enabling technologies on the IoT category are those most often found in digitalization uses. Big data, machine learning and IA technologies are usually found in the customer domain uses, which are key when taking into consideration that an end-user-centric vision is usually associated with the digital transformation, according to the literature.

A review of business models of experiences has been carried out, focusing on the countries selected for the project, but also considering the relevance of the initiative and the availability of accessible information. Thus, initiatives in the UK, Germany, USA, Finland and France have been reviewed. It should be noted that several of them are operating throughout Europe and even globally. Most of the business models reviewed offer cost savings to users, through improvements in service flexibility or cost savings from automation or switching the service provider (to a more efficient one). Also, these businesses models have additional benefits related to sustainability, comfort, energy security, service reliability, among others.

One of the obstacles to access most of the cases reviewed is the availability of information (with the detail of the Canvas model) that could be accessed in an expeditious manner. Thus, a number of businesses and services that were of interest were at the level of research projects or papers (without a business focus) or with very little commercial information available.

The research team analyzed how digital uses and applications could support or incentivize the development of the measures included in the updated NDC proposal and the carbon neutrality target by 2050. In general, most of the digital uses/application identified in this Chapter are not included explicitly in the NDC. For example, DSM, Storage and VPP are digital application that can contribute to the integration to more variable renewable energy source, and therefore, to facilitate the decommission of coals plants (or accelerate) and integrate more renewable level at distributed level. In this case, probably these digital applications will not add additional emissions reduction to the current projection in the NDC. Shared mobility, Autonomous vehicles, Smart traffic, V2G applications can promote the electromobility mitigation action included in the NDC, but in general term, these digital uses promote the sustainable transport and could contribute with addition emission reductions. Other uses and applications, not currently included in the NDC, also have been identified. Smart industry, process optimization (robotic, 3D printer, etc.), smart lighting, smart homes, are examples of digital uses which are not include in NDC, so the development of this application could reduce GHG emission from transport, industry, and residential sector.

According to the international review developed in this project, some of the digital applications and enabling technologies that will deliver a greater contribution or benefit worldwide in the long term are:

- Blockchain: Used at decentralized energy transactions, origin/certification of renewable energy, metering and billing, etc.
- Artificial intelligence and Machine Learning: Used at enhanced forecasting models, new insights into large operational asset data sets, etc.
- Drones and Remote Sensing: Used at wind turbine inspections enhancing safety, mapping using satellite data, automated wind resource assessment, chemical and fuel monitoring, etc.
- Big Data and Data Management: Used for benchmarking of asset performance, for capturing, storing and processing large amounts of data associated with the operation of the system and the operation of the market.
- X as a Service: Used at companies seeking to optimize their energy use through innovative, integrated solutions for the users.

- Micro grids and associated enabling technologies: It include IoT through Smart Sensors or Cloud services for the operation of this use and applications complementary to microgrids, such as Demand Side Management and Energy Storage. From the perspectives of many of the key countries (e.g. Germany), DSM is a great measure to use flexibility of loads, DG, storages etc. to balance and optimally use volatile and fluctuating renewables. This is only feasible with a high degree of automation and digitization.

Regarding these applications, their state of development in Chile is diverse in the different sectors in which they are used. In the case of blockchain and Big Data and Data Management, they are at a very relevant level of development, especially for the handling and secure exchange of information, certification, platforms for traceability and as an enabling tool for new energy assets and products to participate in energy markets. The rest of the applications are in a much lower state of development, mainly due to the cost of technologies, lack of data sovereignty, incompatible regulations and bad decisions at the state level (for instance, the problem of smart meters), in addition to a greater impulse required from the state, in its exemplary role in most of these advances.

Regarding the actions and regulations that need to be implemented for the massification of these applications in the country; although our country has good conditions in terms of coverage and access to mobile Internet, technological and infrastructure capacities, among others; there are still limitations in these aspects, which do not allow certain uses and technological applications to enter a level of maturity similar to that of developed countries. Aspects such as regulations, standards, certifications, access to economic resources (or economic incentives), information security and sovereignty, among others; still have a considerable gap with developed countries. Thus, it is important to consider policies to increase public investment in digital infrastructure, build a large-scale ICT infrastructure that supports public services, including the massification of 5G technology and AI. Also, it is very relevant to adopt common data architectures and standards to reduce errors and increase the quality, reliability and security of devices and services, and to facilitate economies of scale and data exchange between different institutions. On the other hand, it is key to reduce the digital gap between the different territories of the country, especially in the access to technologies such as mobile and fixed Internet of last generation (5G and optical fiber) to transport the great amount of data coming from the digitalization processes.

Additionally, it is necessary to strengthen personal data protection laws and policies for the public and private sectors, the development of pilot programs to promote the use of different digital applications and policies to encourage investment by individuals in projects associated with the digitalization of the energy sector. Cyber security is fundamental to support this digital transformation process. This must be aligned with national cyber security policy. This implies having a robust and resilient information infrastructure, prepared to resist and recover from cyber security incidents, protecting the information infrastructure and demanding differentiated cyber security standards.

A key challenge with digital transformation in our country is keeping pace with technological change and user adoption rates. For this, education and capacity building at the level of industry users and individuals is essential. In fact, a lack of digital skills and lack of digital mindset are the main barriers to digitalization. According to the Harvard Business Review[23] the reason why some digital transformation initiatives fail is that although most digital transformation initiatives enable efficiency gains and customer intimacy, if people lack the right mindset to change and the current organizational practices are flawed, digital transformation will simply magnify those flaws.

Finally, although we have seen that the technology is available to enable digital transformation and it is possible to train users of these technologies, there is still a fundamental element that must exist for digitization to be successful. This corresponds to promoting an individual mentality oriented towards digitalization along with a collective mentality, which goes to the core of institutions' culture and modifies our current ways of working. In the case of energy companies, this change must focus on collaboration, innovation, networking and breaking down departmental niches. Building a new business culture with the digital at its core means that each employee must adhere to the objectives and digital vision of the organization. Digitalization will not only enable a variety of new services and interactions, but also enable paradigm changes in the ways of doing businesses.

[23] https://hbr.org/2019/03/digital-transformation-is-not-about-technology

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Chapter 1

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Annex

Use map

Empty cells in the table mean no information was available.

Class		Sector	Development phase	Countries where it is developed.	Countries/regions where it is used (if applies).	What use(s) it has / what problem is solving.	Organizations/institutions involved in the development	Funding mechanism/ origin.	Link to a country/region policy (if applicable).	Information (kind/content) required for the application/use.	Key factors needed for the application/ use.	Specific/special regulation required for the application/use.	Potential benefit to the energy system and to society.	Does it provide resilience?	Current status of the application/use in Chile.	Forecast of future demand for the application/use.	References
Smart grid	Smart substation	Industry, Electricity generation	On the market	Finland	Finland	Power Grid Security	Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland)	Public		Network information and status	High investment cost (ICTs in particular) & Information security		Favorable against the climate crisis favorable by allowing greater penetration of NCRE and Distributed resources	Yes	Low	Medium	(Dileep, 2020)
	Feeder automation	Electricity generation	On the market	France, Sweden, USA, South Korea, Singapore	France, Sweden, UK, USA, South Korea, Singapore	Grid Management	Schneider Electric, Siemens	Private		Network information and status, Geographical location of DER	Distribution of added value for investment & Regulation (quality standards and supply security)		Favorable against the climate crisis favorable by allowing greater penetration of NCRE and Distributed resources, Greater connectivity with the end user	Yes	Low	Medium	(Dileep, 2020)

	Microgrids	Transportation, Industry, Buildings, Electricity generation, Public Sector	Testing	UK, Germany, USA, Singapore, Japan, Sweden, China		Decarbonization, Grid Management, emission reduction	BDEW (Germany), Department of Energy (USA), New Energy and Industrial Technology Development Organization (Japan), E.ON (Sweden), Energy Market Authority (Singapore), State Grid Corporation of China (SGCC), China Southern Power Grid (CSPG) (China), UK Research and Innovation (UK)	Public	US Department of Energy's Microgrid Initiative	Network information and status	Technical barriers, Regulation & Lack of incentives to flexible resources.		It allows the entry of more distributed resources and favors distributed generation, reducing costs and emissions	Yes	Low	Medium	(Barai et al., 2016; Dileep, 2020; Parhizi et al., 2015)
DER management	DSM/DR	Transportation, Industry, Buildings, Electricity generation, Public Sector	On the market	Germany, Finland, Japan, UK, USA, China, Singapore	Germany, Finland, Japan, UK, USA, China, Singapore	Grid Management, End user participation, Emission reduction	BDEW (Germany), Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland), Ministry of Economy, Trade and Industry - Agency for Natural Resources and Energy (Japan), Smart City Sweden (Sweden), GridBeyond & Office of Gas and Electricity Markets (UK), Energy Information Administration (USA), NingXia Power Demand Side Management Platform & Ministry of Industry and Information Technology (China), Ministry of Trade, Industry and Energy (South Korea)	Public	"Smart Nation Initiatives" (Singapore)	Network information and status, Energy price, Geographical location of DER	Regulation, Enabling technologies, Maturity of smart appliances & Access to information.	Yes. Example: Specific requirements and rules to participate in energy markets.	It allows the entry of more distributed resources and favors distributed generation, reducing costs and emissions, greater connectivity with the end user	Yes	Low	High	(Dileep, 2020; Lampropoulos et al., 2013; Murthy Balijepalli et al., 2011; Weigel & Fischedick, 2019)
	Energy storage							Public						Yes	Low	High	

		Transportation, Industry, Buildings, Electricity generation, Public Sector	On the market	Germany, Finland, Japan, UK, USA, China, France, South Korea, Singapore	Germany, Finland, Japan, UK, USA, China, France, South Korea, Singapore	sufficiency, flexibility	BDEW (Germany), Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland), TEPCO & Ministry of Economy, Trade and Industry - Agency for Natural Resources and Energy (Japan), Moixa & DNVGL / Renewable Energy Association (UK), Ministère de l'Économie, des Finances et de la Relance (France), Ministry of Trade, Industry and Energy (South Korea), Energy Market Authority (Singapore)			Network information and status, Energy price.	High investment, Regulation & Potential conflict with generators	Yes. Example: Specific requirements and rules to participate in energy markets.	Greater robustness and flexibility, complement to NCRE				(Dileep, 2020; Koirala et al., 2018; Weigel & Fischedick, 2019)
	VPP	Industry, Buildings, Electricity generation	On the market	Germany, Japan, UK, USA, Singapore	Germany, Japan, UK, USA, Singapore	Flexibility	BDEW (Germany), Ministry of Economy, Trade and Industry - Agency for Natural Resources and Energy (Japan), Moixa (UK), Department of Energy (USA), Energy Market Authority (Singapore)	Public		Network information and status, Energy price, Geographical location of DER	Regulation, Enabling technologies, Connectivity and computational cost	Yes. Example: Specific requirements and rules to participate in energy markets.	It allows the entry of more distributed resources and favors distributed generation, reducing costs and emissions, greater connectivity with the end user	Yes	Low	Medium	(Dileep, 2020; Lv et al., 2018; Weigel & Fischedick, 2019)
	Distributed energy (electricity/DG & gas)	Industry, Buildings, Electricity generation, Public Sector	Mature	Germany, Japan, Sweden, China, Singapore, South Korea	Germany, Japan, Sweden, China, Singapore, South Korea	Decarbonization, Grid Management	BDEW (Germany), Ministry of Economy, Trade and Industry - Agency for Natural Resources and Energy (Japan), Swedish Smart Grid (Sweden), National	Public	"Korean New Deal", "Smart Nation Initiatives" (Singapore)	Energy price, Network information and status	Regulation & Upgrade of the grid	Yes. Example: Specific requirements and rules to participate in energy markets.	It allows the entry of more distributed resources and favors distributed	Yes	Medium	High	(Dileep, 2020; Mehigan et al., 2018)

							Development and Reform Commission & Ministry of Industry and Information Technology (China), Ministry of Economy and Finance (South Korea), Shell / Singapore International Energy Week (Singapore)						generation, reducing costs and emissions				
Customer domain	Prosumer & P2P trades	Industry, Buildings, Electricity generation	On the market	Germany	Germany	Market Management, end user participation	BDEW (Germany)	Public	“Smart Nation Initiatives” (Singapore)	Energy price, Information on contracts and fees	Infrastructure to measure & Reduced types of energy product		Greater connectivity with the end user	No	Low	High	(Dileep, 2020; Weigel & Fischedick, 2019)
	Retailing, billing & customer orientation	Transportation, Electricity generation, Finance, Public Sector	Testing	Germany, Finland	UK, Singapore	Market Management, end user participation	BDEW (Germany), Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland),	Public	“Smart Nation Initiatives” (Singapore)	Energy price, Information on contracts and fees	Regulatory, Infrastructure & No market competition assurance	Yes. Example: The differentiation between utility and retail companies.	Greater connectivity with the end user, Reduction in charges for electricity	No	Low	Medium	(Dileep, 2020; Weigel & Fischedick, 2019)
Process management	Process optimization & automation (gas, oil & coal)	Transportation, Industry, Buildings, Electricity generation	Testing			Grid Management, Market Management				Network information and status, process-specific information that is optimized/automatized	High cost, Employee resistance & Infrastructure		Process cost reduction	No	Low	Low	(IEA, 2017)
	Emission monitoring	Industry, Electricity generation	Mature	South Korea	South Korea	Emission reduction	Ministry of Environment (South Korea)	Public	"Korean New Deal", "Smart Nation Initiatives" (Singapore)	Emission restriction regulations	Economic incentives & High cost	Yes. Example: Specific rules on emission metering	Favorable against the climate crisis through the emission reduction	No	Low	Medium	(IEA, 2017)
Mobility	Transportation for personal use	Transportation, Buildings	On the market	Germany, Finland, Japan, Sweden, UK,	Germany, Finland, Japan, Sweden, UK, USA, China, France,	vehicle/traffic management	BMVi (Germany), Business Finland (Team Finland, Ministry of Economic Affairs and Employment)	Public	"Korean New Deal", "UK's Road to Zero Strategy", "UK's	Traffic congestion signs	Vehicle connectivity, Regulation, High investment &	Yes, Example: Definition of communication	Optimization of time and safety of the	Yes	Low	Medium	(Adler et al., 2019; Chen et al., 2020; Choudhary &

				USA, China, France, South Korea, Singapore	South Korea, Singapore		(Finland), Ministry of Economy, Trade and Industry - Agency for Natural Resources and Energy (Japan), Smart City Sweden (Sweden), Moixa & Innovate UK (UK), Department of Transportation & Department of Energy (USA), Ministry of Transport & Ministry of Ecology and Environment (China), Ministère de l'Économie, des Finances et de la Relance (France), Ministry of Economy and Finance, Ministry of Environment, Ministry of Trade, Industry and Energy & Ministry of Science and ICT (South Korea), Smart Nation and Digital Government Office (Singapore)		Future of Mobility: Urban Strategy"		Interoperability	protocols and spectre allocation.	population				Umang, 2015; IEA, 2017)
	Public transport	Transportation				Emission reduction, Grid Management			"Korean New Deal", "Smart Nation Initiatives" (Singapore), "UK's Road to Zero Strategy", "UK's Future of Mobility: Urban Strategy"	Traffic congestion signs, Network information and status (handling it as DER)	High investment & Public transport over private		Favorable against the climate crisis through the emission reduction, Optimization of time and safety of the population.		Medium	High	
	Transport cargo	Transportation				Emission reduction, Grid Management			"Korean New Deal", "UK's Road to Zero Strategy"	Traffic congestion signs	ICT skills		Favorable against the climate crisis through the emission reduction.		Medium	Medium	
	Shared mobility	Transportation	On the market	Sweden, China	Sweden, China	Emission reduction	Smart City Sweden (Sweden), Ministry of Housing and Urban-Rural Development (China)	Public	"Smart Nation Initiatives" (Singapore), "UK's Future of Mobility: Urban Strategy", "UK's Future of Mobility: Urban Strategy"	Availability and demand of shared vehicles	Regulation, High investment, Parking places, Rates for use, Security & Payment systems	Yes. Example: Taxation rules on private vehicles, regarding its size, used for public transport.	Favorable against the climate crisis through the emission reduction, Population time optimization.	No	Medium	Medium	(Chen et al., 2020; IEA, 2017)
Data management	Predictive maintenance	Transportation, Industry, Buildings, Electricity generatio	On the market	Germany, Singapore	Germany, Singapore	Power Grid Security	BDEW (Germany), Singapore-IEA (Singapore)	Public		Machinery overview	Infrastructure, Data, Unrealistic expectations & trust		Maintenance cost reduction.	Yes	Low	Medium	(Hossain et al., 2019; Mobley, 2002; Weigel &

		n, Public Sector															Fischedick, 2019)
	Forecasting and predictive analytics	Transportation, Industry, Buildings, Electricity generation, Finance, Public Sector	On the market	Germany, Finland, UK, USA	Germany, Finland, UK, USA	Grid Management	BDEW (Germany), Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland), Department of Energy (USA)	Public	"Korean New Deal"	Historical data, Weather information	Infrastructure, Historical data, Unrealistic expectations		Favorable against the climate crisis favorable because by reducing uncertainty, it allows a greater entry of NCRE, in addition to contributing to the planning of the system.	Yes	Low	High	(Hossain et al., 2019; Weigel & Fischedick, 2019)
Smart city	Smart lighting	Industry, Buildings, Public Sector	On the market	Finland, Sweden , USA, China, Singapore	Finland, Sweden, USA, China, Singapore	Energy efficiency	Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland), Department of Energy (USA), Ministry of Housing and Urban-Rural Development (China), Smart Nation and Digital Government Office (Singapore)	Public	“Smart Nation Initiatives” (Singapore)	Weather conditions, Sensor data	High investment, Incentives, Cybersecurity, Interoperability, Standards	Yes. Example: Security specifications for public lighting	Greater security for the population, Consumption reduction for the network.	Yes	Low	High	(Hewlett Packard Enterprise, n.d.; Sikder et al., 2018)
	Smart traffic	Transportation, Industry, Buildings, Public Sector	Testing	Japan, China, USA, UK, Finland, South Korea		vehicle/traffic management	National Police Agency, the Ministry of International Trade and Industry, the Ministry of Transport, the Ministry of Posts and Telecommunications, and the Ministry of Construction (Japan), National	Public	“Smart Nation Initiatives” (Singapore)	Traffic congestion signs	Infrastructure, Large amounts of data, Interoperability		Population time optimization, Vehicular decongestion.	No	Low	Medium	(Choudhary & Umang, 2015; Hewlett Packard Enterprise, n.d.)

							Development and Reform Commission (NDRC) and Ministry of Transportation (MOT) (China), U.S. Department of Transportation (USA), SWECO (UK), Intelligent Traffic Management Finland Ltd. (Finland), Seoul's Intelligent Traffic System (South Korea)										
	Smart home & building	Industry, Buildings	On the market	Germany, Japan, Sweden, UK, China, France, South Korea, Singapore	Germany, Japan, Sweden, UK, China, France, South Korea, Singapore	Energy efficiency, user accessibility	Ministère de l'Économie, des Finances et de la Relance (France), Ministry of Economy, Trade and Industry (Japan), Smart City Sweden, Swedish Smart Grid & Swedish Energy Agency / Kungliga Tekniska Högskolan (Sweden), Electricity System Operator (UK), Department of Energy (USA), Ministry of Trade, Industry and Energy (South Korea), Smart Nation and Digital Government Office (Singapore)	Public	"Korean New Deal", "Smart Nation Initiatives" (Singapore)	Energy price, Information on contracts and fees	Cybersecurity and sovereignty of information	Yes. Example: Regulation on private data management.	Saves residents time by automating and simplifying domestic tasks, also reduces energy consumption by reducing the load on the network.	Yes	Low	High	(Dileep, 2020; Hewlett Packard Enterprise, n.d.; Jiang et al., 2004; Zhang et al., 2019)
	Smart industry	Industry, Finance, Public Sector	On the market	Japan, USA, China, France, South Korea	Japan, USA, China, France, South Korea	Logistics processes optimization	Council for Science, Technology and Innovation (Cabinet Office) (Japan), Department of Energy & International Trade Commission (USA), National Development and Reform	Public	"Korean New Deal", "Smart Nation Initiatives" (Singapore)	Machinery overview, Energy price	Standardization, Knowledge of technology, investment in equipment and training		Optimization of time in industrial processes, reduction of emissions thanks to intelligen	Yes	Medium	Medium	(Hewlett Packard Enterprise, n.d.; ISO 8373:2012(En), Robots and Robotic Devices —

							Commission (China), Ministry of Economy and Finance & Ministry of Science and ICT (South Korea)						t transport				Vocabulary, n.d.)
	Smart farm	Industry	On the market	South Korea	South Korea	Energy efficiency, climate crisis	Ministry of Science and ICT (South Korea)	Public	"Smart Nation Initiatives" (Singapore)	Weather conditions, Prediction of availability of water resources, Sensor data	Internet access, compatibility between different software/hardware products		Improvement in the quality and quantity of crops, reducing costs in the agricultural market	No	Low	Low	(Hewlett Packard Enterprise, n.d.)
	Smart parking	Transportation, Public Sector	Testing	Finland	US	Energy efficiency, traffic/vehicle management	Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland),	Public	"Smart Nation Initiatives" (Singapore)	Traffic congestion signs, Sensor data	Cybersecurity, investment in equipment and training and real-time information system		population time optimization	Yes	Low	Medium	(Hewlett Packard Enterprise, n.d.)
	Smart waste management	Industry, Buildings, Public Sector	Testing	Denmark		Energy efficiency, emission reduction	Municipality of Kolding (Denmark)	Public	"Korean New Deal", "Smart Nation Initiatives" (Singapore)	Geographical location of garbage containers, Sensor data	Training of citizens, investment for infrastructure		reduction of costs in garbage management, favorable against the climate crisis through the reduction of emissions	No	Low	Low	(Hewlett Packard Enterprise, n.d.)
	Smart fleet management	Transportation, Industry, Public Sector	On the market	Finland	Finland	Energy efficiency, vehicle/traffic management	Business Finland (Team Finland, Ministry of Economic Affairs and Employment) (Finland),	Public	"Smart Nation Initiatives" (Singapore)	Traffic congestion signs	Cybersecurity and information sovereignty , vehicle maintenance		favorable against the climate crisis through the reduction of fuel consumption,	No	Low	Medium	(Hewlett Packard Enterprise, n.d.)

													reduction of maintenance costs, reduction of vehicular congestion and optimization of the population's time				
Other	Market management & operation	Electricity generation, Finance	On the market		UK	Market Management	EC-MAP (Energy Consumer Market Alignment Project)	Private	"Smart Nation Initiatives" (Singapore)	Network information and status, Energy price	Regulation for the new services and agents	Yes. Example: Regulation on operators, market monitors, serving entities, etc.	cost reduction for the system through smart market management	No	Medium	High	(Dileep, 2020; Weigel & Fischedick, 2019)
	Ancillary services	Transportation, Industry, Buildings, Electricity generation	On the market		USA, China, UK	Grid Management, Flexibility	Department of Energy and Climate Change (UK)	Public		Network information and status, Energy price	High computational capacity	Yes. Example: Regulation on operators, market monitors, serving entities, etc.	favorable against the climate crisis favorable by allowing greater penetration of NCRE and Distributed resources	Yes	Medium	High	(Dileep, 2020; Weigel & Fischedick, 2019)
	Energy management	Transportation, Industry, Buildings, Electricity generation	On the market	Germany, Japan, Sweden, UK, France	Germany, Japan, Sweden, UK, France	Grid Management, Market Management	Ministère de l'Économie, des Finances et de la Relance (France), Ministry of Economy, Trade and Industry & Japan External Trade Organization (Japan), Smart City Sweden (Sweden), Department for Business, Energy &	Public	“Smart Nation Initiatives” (Singapore)	Network information and status, Energy price, Sensor data	Economic incentives, house technical expertise	Yes. Example: Regulation on metering equipment ownership and uses.	favorable against the climate crisis favorable by allowing greater penetration of NCRE and Distributed	Yes	Low	High	(Mariano-Hernández et al., 2021; Nguyen et al., 2018; Zafar et al., 2020)

							Industrial Strategy (UK)						resources, Greater connectivity with the end user				
	Operation (monitoring/control/ reporting)	Electricity generation	Testing	UK, USA		Power Grid Security, Grid Management	TSOs (Europe), ISOs (US)			Network information and status, Energy price	User information privacy policies	Yes. Example: Regulation on standards to ensure interoperability.	Favorable against the climate crisis favorable by allowing greater penetration of NCRE and Distributed resources, Improve network security and reliability.	Yes	Medium	Medium	(Zafar et al., 2020)
	Teleworking	Transportation, Industry, Buildings, Electricity generation, Finance, Public Sector	Mature	Worldwide	Worldwide	User accessibility	doesn't apply	doesn't apply	"Korean New Deal"	Technological availability, knowledge of use by users	Connectivity at residential level	Yes, Example: Regulation on working hours for teleworkers.	optimizes users time, and allows them to continue participating in work activities due to adverse situations (e.g. COVID-19) or by user choice	No	Medium	High	(Hook et al., 2020)

Standards associated with digital applications and uses

Standards	ANSI C12	ANSI/ASHRAE	ANSI/CEA 709	ANSI/CEA 852	CTA 2045	IEC 60255	IEC 60870-5	IEC 60870-6	IEC 61000	IEC 61334	IEC 61850	IEC 61851	IEC 61869-9:2016	IEC 61970	IEC 62056	IEC 62282	IEC 62325	IEEE 1377-2012 (ANSI C12.19)	IEEE 1701-2011 (ANSI C12.18)	IEEE 1702-2011 (ANSI C12.21)	IEEE 1815	IEEE 1901	IEEE 2030	IEEE C37.238	IEEE C37.239-2010	IETF RFC-6272-2011	ISO 15118	ISO/IEC 14908	ISO/IEC 15067	ITU T-G.9903	MultiSpeak Security-V1.0	NAESB	NEMA SG-AMI 1-2009 (R2015)	NISTIR	OASIS	OpenHAN	OpenADR 2.0 Profile A OpenADR 2.0 Profile B	SAE J1772-2017	SAE J2836-Use-Cases-(1-3) SAE J2836/1	SAE J2847/1:2010	Security Profile for Advanced
Uses / Applications	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smart substation	x		x			x			x	x	x		x	x	x		x					x	x	x	x	x		x						x		x					
Feeder automation	x		x			x			x		x			x								x	x	x	x	x		x						x		x					
Microgrids									x					x														x													
DER management	x	x	x	x	x	x			x	x	x			x	x	x	x					x	x	x	x	x	x	x		x	x			x				x	x	x	
DSM/DR			x		x					x	x			x								x	x	x	x	x	x	x		x	x			x	x		x				
Energy storage									x		x					x						x				x					x			x							
VPP											x						x									x		x			x			x							
Distributed energy (electricity/DG & gas)	x	x	x						x		x			x			x	x	x	x	x	x		x	x	x		x			x			x				x	x	x	
Prosumer & P2P trades																																									
Retailing, billing & consumer orientation									x		x						x							x	x	x		x				x		x							
Process optimisation & automation (gas, oil & coal)																																									
Emission monitoring																															x										
Transportation for personal use		x			x					x	x	x											x			x	x	x	x	x	x			x				x	x	x	
Public transport		x			x					x	x	x											x			x	x	x	x	x	x			x				x	x	x	
Transport cargo		x			x					x	x	x											x			x	x	x	x	x	x			x				x	x	x	
Shared mobility		x			x					x	x	x											x			x	x	x	x	x	x			x				x	x	x	
Predictive maintenance	x		x																																						
Forecasting and predictions																	x																								
Smart lighting	x	x	x	x	x																																				
Smart traffic	x		x	x																							x														
Smart home & building		x	x	x	x				x		x						x					x	x			x	x	x		x				x		x					
Smart industry	x	x	x	x	x						x											x	x			x								x							
Smart farm	x			x	x																																				
Smart parking	x			x	x																																				
Smart waste management	x			x	x																																				
Smart fleet management	x			x																																					
Market management & operation									x		x			x	x		x							x	x	x		x						x	x		x				
Ancillary services						x			x		x			x	x												x	x													
Energy management		x	x	x	x		x		x		x			x								x	x	x	x	x		x	x	x	x			x							
Operation (monitoring/control/reporting)	x		x		x	x	x	x	x		x			x	x		x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Teleworking																																									

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