Deliverable 5.2

Analysis of the potential benefits to the circular economy models in Brazil, Chile, Mexico and Uruguay from application of Industry 4.0

Project: Assessment of the current status of the circular economy, for development of a roadmap for Brazil, Chile, Mexico and Uruguay

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Factor
Ideas for change

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CONTENTS

TABLES

ANNEXES

ABBREVIATIONS

AI	Artificial Intelligence
ANIQ	Asociación Nacional de la Industria Química; National Chemical Industry Association
AR	Augmented Reality
CAMIPER	Cámara Minera del Perú; Mining Chamber of Peru
CE	Circular Economy
CNI	Confederación Nacional de la Industria; National Confederation of Industry
ESCO	Energy Service Company
FAO	Food and Agriculture Organization of the United Nations
FINEP	Research and Projects Funder
GHG	Greenhouse gases
GIZ	Gesellschaft für Internationale Zusammenarbeit; German Corporation for International Cooperation
ICT	Information and Communications Technology
IIoT	Industrial Internet of Things
IoT	Internet of Things
ISPA	International Society of Precision Agriculture
MCTI	Ministerio de Ciencia, Tecnología, e Innovación; Ministry of Science, Technology and Innovation
ML	Machine Learning
MRO	Maintenance, Repair and Operations
MSW	Municipal Solid Waste
NDC	Nationally Determined Contributions
OECD	Organisation for Economic Cooperation and Development
PaaS	Product as a Service
PACTI	Planes de Acción sobre Ciencia, Tecnología e Innovación; Science, Technology and Innovation Action Plans
PBS	Polybutylene Succinate
PC	Personal Computer
PET	Polyethylene terephthalate
PHA	Polyhydroxyalkanoates
PLA	Polylactic Acid

PROFEFA	Procuraduría Federal de Protección al Ambiente; Federal Environmental Protection Agency
PTIC	Parque Tecnológico Industrial del Cerro; El Cerro Industrial Technology Park
RFID	Radio-Frequency Identification
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales; Ministry of the Environment and Natural Resources
SME	Small and Medium Enterprise
UNIDO	United Nations Industrial Development Organization
VR	Virtual Reality
WEF	World Economic Forum

1. Introduction

This report presents the results of Deliverable 5.2, **Analysis of the potential benefits of the application of Industry 4.0 to the circular economy models in each participating country as part of Product 5 of the project "Assessment of the current status of the circular economy, for development of a roadmap for Brazil, Chile, Mexico and Uruguay", RFP/UNIDO/7000003530**.

An analysis of current developments in the key technologies of the fourth industrial revolution compatible with the circular economy (CE), will be used to present benefits for the various initiatives identified in each country.

This deliverable is based on the definition of circular business models according to the methodologies presented by the Organization for Economic Co-operation (OECD), the Ellen MacArthur Foundation and the Accenture consulting firm. **The aim of this is to align the initiatives identified in the countries with these models and support their integration of Industry 4.0 technologies**, thus enabling them to make their production processes and services more efficient, optimize their use of resources and energy and develop new business models.

2. Circular business models and their relationship with the technologies of Industry 4.0

2.1 Circular business models

There are several ways to classify circular business models. The Ellen MacArthur Foundation, for example, proposes the "**ReSOLVE Framework**", (Ellen MacArthur Foundation, 2015) which includes business models that refer to regeneration ("Regenerate"), sharing assets ("Share"), optimization ("Optimize") recovering assets and waste ("Loop") and virtualization ("Virtualize").

Meanwhile, both Accenture (Accenture, 2014) and the OECD (OECD, 2019) identify five circular business models:

- **Circular supplies**: Enhance the substitution of traditional raw materials through the input of renewable or reclaimed materials.
- **Resource recovery**: Produce secondary raw materials from waste.
- **Product life extension**: To include both refurbishment and remanufacturing. The goal is to extend the product's useful life.
- **Sharing platforms**: Sharing products and assets.
- **Product as a Service**: Turn products into services, whereby the supplier retains ownership of the product.

Table 1 presents each circular model's key characteristics, natural resource-efficiency driver, subtypes and the main sectors in which it is currently most used.

Table 1. Circular business models
Source: Business Models for the Circular Economy (OECD, 2019) *(OECD, 2019)*

	Circular supply	Resource recovery	Product life extension	Sharing	Product service system
Key characteristic	Replace traditional materials with renewable materials	Produce secondary raw materials	Extend product lives	Increase utilisation of existing products and assets	Provision of services rather than products
Resource efficiency driver	Close material loops	Close material loops	Slow material loops	Shared assets	Operation and maintenance efficiency
Business model sub-types	Cradle to Cradle	Industrial symbiosis Recycling, upcycling, downcycling	Repair, reuse, remanufacture, refurbish	Co-access Co-ownership	Product-oriented, client-oriented, output-oriented
Main sectors	Diverse consumer product sectors	Metal Paper Plastics	Automotive Heavy Machinery Electronic	Transport Lodging Machinery Consumer products	Transport Chemicals Energy

Business models differ at the theoretical level, but are interconnected in practice. Thus, an initiative arising from one of them can generate another circular model. For example, a Product as a Service model may subsequently give rise to the extension of the product's useful life.

The degree of penetration of circular business models is limited and, to date, has only occurred in certain productive sectors, as shown in **Table 2**. This penetration basically depends on the quality of the institutional structure, customer behaviour and the degree of development of digital technology.

Table 2. Market penetration of selected circular business models
Source: Business Models for the Circular Economy *(OECD, 2019)*

Circular business model	Sector	Market penetration	Explanation
Waste as value: recycling	Pulp and paper Metal Plastics	38% 2-30% 13%	Of total global output
Extension: refurbishment	Smartphone	4-8%	Of total annual manufacturing
Extension: Remanufacture	Aerospace Machinery Automotive	2-12% 3-4% 1%	Of total manufactured
Platforms: Co-access	Lodging	1-6%	Of total short-term bookings
PaaS: result-oriented (chemicals)	Automotive Aerospace	50-80% 5-15%	Of total manufactured
PaaS: result-oriented (digital content)	Music Books	50% 25-35%	Of total industry revenues
PaaS: result-oriented (lighting and heating)	Various	4-7.5%	Of potential Energy Service Companies (ESCO) uptake
PaaS: user-oriented (car sharing)	Transport	<1%	Of total global car fleet

It is important to note that circular business models are not widely spread and so there is a great distance to be travelled for their future development. The key to the speed and depth of this journey is to be found in the ability of the country to incorporate Industry 4.0 into the design of its business models. We can say that while the design of the business model takes its inspiration from the concept of the circular economy, its actual implementation will hinge on capacity to respond to the technological challenge of Industry 4.0.

2.2 Circular business models and Industry 4.0 technologies in various sectors

All the Industry 4.0 technologies ("smart technologies") identified in Deliverable 5.1 and reproduced in **Annex 1** are applicable, with greater or lesser degrees of complexity, integration and flexibility, to all circular business models. It must also be taken into account that application of a technology may begin with a particular model and later affect several business models at the same time.

The implementation of Industry 4.0 technologies in circular business models will fundamentally depend on each sector's technological intensity, on the size of companies in the country and on each company's competitive context.

In circular business models, Industry 4.0 technologies seek to increase companies' competitiveness in specific sectors and markets, using three lines of action: automation, connectivity and real-time smart management of large amounts of information. The goal here is to develop a predictive strategy and operational management. This means that companies' competitiveness becomes based on their capacity to anticipate customer expectations. In this regard, it must be noted that in the circular economy, the starting point is the abandonment of the concept of mass production, with its strategy focused on achieving the operational excellence of the production process, in favour of personalized production with a focus on the customer. And this means that the design of the production process is adjusted to customers' changing expectations.

The challenge in this context, therefore, is that of designing a management model able to efficiently anticipate the customer's expectations through a strategy to reduce environmental impact. This challenge is represented not conceptually but in a real way in the different economic sectors.

This is why we shall go on to offer an analysis of the challenges of Industry 4.0 in the most representative sectors of the four countries studied in relation to the circular business model goals. These sectors were chosen on the basis of the initiatives analysed and their importance to the economic and social development of the international framework. The sectors analysed are: agriculture, livestock farming, energy, mining, waste management, and dairy.

2.2.1 Agriculture

According to FAO, the **two major challenges** for the agricultural sector are those of addressing climate change (as this may lead to a potential lowering of crop efficiency) and of responding to constant population growth (FAO, 2017). This growth simultaneously involves a need for greater productivity and quality for the consumption of crops. World agriculture will need to produce approximately 70% more food than in 2006. In addition, price pressures in the global market force farmers to focus on efficiency and large-scale high-quality production.

These challenges require a flexible and effective production model. This means that high real-time knowledge is needed of all the variables that affect its efficiency, such as: the environment in which the crops are grown, soils, disease incidence, optimal input management and the genetic characteristics of seeds, all in order to be more competitive. Only an agricultural operational design based on advanced technology will provide the knowledge required of the physical circumstances inherent to production. This technology should also make it possible to conduct management down to the individual farm level, including with significant variability within the same plot. The goal is to produce more efficiently in more complex environmental circumstances.

The response to this challenge is called **"precision farming"**, and its key characteristic is to improve farms' resilience, through the incorporation of the new technology now available. The *International Society of Precision Agriculture* (ISPA) defines precision agriculture as: "A management strategy that gathers, processes, and analyses temporal, spatial, and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production" (Universitat de Lleida, s.f.).

This model of agriculture potentially involves all the circular business models identified above in this report and the inherent objective of supporting them using smart technology is to increase the competitiveness of companies by means of three axes:

- **Social:** Increasing the value of ecosystem services in the farm's community and region.
- **Environmental:** Reducing the impact associated with agricultural activity (limiting the dispersion of nitrogen).
- **Efficiency:** Increased competitiveness through more-efficient practices and improved management, including reduced water, input, and energy consumption, and lower incidence of crop diseases through the use of varieties that are increasingly resistant and suited to the environment.

Regarding the objective of the technologies applied to the circular economy models involved in precision agriculture, the following basic steps are particularly noteworthy (Universitat de Lleida, s.f.):

- **Knowledge of the specific circumstances of the crops in question:** This will make it possible to overlay different types of information, such as: historic yields, soil analysis, maps and satellite positioning, progress of the harvest, even down to plant level and other environmental circumstances that affect production, which will enable the design of crop input management more-efficient choices of time, amount and application.
- **Analysis and application:** After extraction and analysis of the data determining the flexibility of the production process of the plots tailored to their specific circumstances, the next step is application at the precise time of the precise type and amount of seed and fertilizer. Thus, within any one plot, it will be possible to secure a greater level of precision and efficiency using the sensors embedded within it and in the tractors and the farm's other assets, enabling variable-density sowing and even the automatic, specific application of nitrogen and plant protection products.

Therefore, the technologies that could potentially be applied in combination with assets in this type of management may be summarized as follows: robots, sensor-equipped autonomous vehicles, drones, satellite images, the Internet of Things, mobile applications, big data and artificial intelligence (Machine Learning).

2.2.2 Livestock farming

Overall, there are **three major challenges** that will define the future development and competitive context of livestock farming:

- The great pressure that it exerts on ecosystems and awareness that it has a significant impact on climate change.
- The potential increased spreading of animal diseases that threaten human health, due to increased international trade flows and the concentration of livestock units in proximity to human populations.
- The role that the sector needs to play to alleviate poverty and ensure food security.

It should be noted that these challenges are generic in nature and need to be considered more finely when put against the specificities of livestock production in each particular country. In Uruguay, for example, livestock farming is primarily conducted on natural grassland and its NDC has goals for improving the efficiency of meat production against greenhouse gas emissions (Ministerio de Agricultura, Ganadería y Pesca, 2020).

Regardless of nuance, it is acceptable to consider that a new model of livestock farming, known as **"Precision Livestock Farming"** can play a decisive role towards resolving these generic challenges. There is no formal definition of precision livestock farming, but in academic and business circles, precision livestock farming is taken as "the coordinated use of sensors for measuring animal phenotypes, environmental and physiological parameters and systems to exchange, store, process, and provide livestock farmers with information to help them in their daily decision making, aided by technology. (Díaz Rodríguez, Rodríguez, Montañés Foz, Bodas Rodríguez, & García García, 2020)"

The drive towards precision livestock farming came after precision agriculture, but it basically shares the same lines of action. We can say that this new understanding of livestock production is fully aligned with the circular models presented. The ultimate goal of precision livestock farming is based on the individualized management of the livestock unit and livestock to achieve higher levels of efficiency.

According to sources of information on the sector (Díaz Rodríguez, Rodríguez, Montañés Foz, Bodas Rodríguez, & García García, 2020), the **incorporation of new information and communication technologies (ICT)** in the day-to-day management of the farm to gather information about parameters will improve the farmer's profits while simultaneously reducing the environmental impact of production processes and providing greater health and well-being for the animals and, consequently, a higher-quality final product. Specific and even individualized real-time information management has the potential to take livestock farming forward to a predictive model that will enable the manager to anticipate circumstances to gain efficiency and quality. The application of smart technology to the sector will play a decisive role in increasing its competitiveness, the use of artificial intelligence and such technologies as the Internet of Things and big data for the improvement of intensive livestock farming through the optimized care of animals becoming increasingly standard practice.

According to Díaz Rodríguez and others (Díaz Rodríguez, Rodríguez, Montañés Foz, Bodas Rodríguez, & García García, 2020), using sensor devices such as smart collars, virtual fencing, feeder sensors, drones, movement sensors and robotic milking and cleaning will make it possible to monitor animals' physical and biological parameters and obtain and process precise real-time data in a cloud computing environment.

This will make it possible to know what variables are influencing animal welfare, to rapidly detect any anomalies and react quickly to anything indicating a feeding or health problem. These technologies maximize each individual animal's potential, enable the early detection of diseases and help minimize the use of drugs, through preventive health measures.

The latest technology to arrive in the sector, and which is likely to govern future traceability and commercial transactions in the world beef market is Blockchain, which will be able to quickly and cheaply record a very large number of operations on any number of computers with a total assurance that no-one can subsequently delete or amend anything that has been recorded.

Technology, sensors, robots and artificial intelligence will also play a crucial part in the operation of plants for converting waste into energy and fertilizer.

2.2.3 Dairy sector

The technological advances in the dairy sector are closely related to those in the livestock sector and, therefore, those items mentioned under livestock also apply to the management of dairy herds.

The fundamental **challenges** of innovation for the dairy sector relate to process automation technologies associated with quality control and product safety using sensors and cloud platforms (Erbes, Gutman, Pablo, & Robert, 2019). These challenges fall into four groups:

- **Total automation of production processes**, combining software, hardware, sensors and industrial equipment in companies with integrated automation systems. These systems enable integrated control of the entire process, from the pre-processing of the milk and the processing and checking of final batches through to the sharing and centralizing of information to ensure the safety and quality of the raw material and products.
- **Robotization** of partial or individual processes (selection and placement robots) as can be seen in some cheese-manufacturing companies and at the packing and palletizing stages. Robotization of the entire production process has not yet been achieved.

- **Technologies based on the digital domain**, for firms' commercial management tasks and for ensuring the traceability of products and during the company's various production stages, including storage and logistics. Blockchain technology is starting to spread among these, to ensure traceability and control, and communication throughout every stage of the dairy value chain. These technologies guarantee food quality and safety, ensure control of the origin of each input and facilitate just-in-time strategies and production "customization", boosting the co-evolution of technological and organizational innovations.
- **Systems, sensors and control software for effluents, fertilizers and soil quality.**

What this demonstrates is the great impact and relevance of Industry 4.0 to the development of new circular-economy business models simultaneously leading to reduced environmental impact and economic efficiency.

2.2.4 Mining

The mining industry has three characteristics that determine its competitive context: (i) it is an intensive user of assets, for which reason its maintenance and operation costs are very high; (ii) it has considerable environmental impact that makes it difficult to defend its social reputation; and (iii) staff health and safety is a key factor in the design of its operations, thus affecting its cost.

In this context, the thrust of the **strong inclusion of new digital technologies** throughout the mining process and the automation that has gradually been taking place in companies, from exploration through to distribution and logistics has an important logic from the standpoint of improving its competitiveness, since it enables the monitoring of the entire process, which brings an opportunity to carry out predictive projections that enable personnel and environmental safety standards to be raised while saving on maintenance and operations costs.

The World Economic Forum (WEF) has identified the areas that will play a very important role in the automation and digital transformation of mining (World Economic Forum, 2017). Large mining companies initially focus on the stand-alone control and automation of certain activities and systems. They then begin to locate infrastructure and telecommunications services in all areas of the mine before finally automating, controlling and digitizing all activities.

The development of a fully automated and controlled mine involves a number of stages and technologies. Starting from an initial phase of individual automation, the process is begun with the installation of telecommunications infrastructure in all under- and above-ground areas of the mine. This will include structured cabling, fibre optics, control rooms, wireless links, Wi-Fi networks, telephony equipment, servers, devices for extending the cellular signal, mobile communications nodes, closed circuit television, access control, fire detection and suppression, and radio communication. The purpose of this infrastructure installation is to provide telecommunications services, such as digital radio communications, internet telephony, video, RFID systems, a cellular signal and Wi-Fi connectivity (World Economic Forum, 2017).

The next step is the digitalization of the process and integration of all its component systems, that is, the creation of real-time virtual copies of every mining activity through information provided by sensors or electronic devices located on equipment, machines, vehicles, persons, etc. The systems to be digitalized and integrated include location and tracking, evacuation, collision avoidance, geofencing, energy monitoring, gas monitoring, equipment telemetry and motion video. The idea is to manage the information on every system in the mining process using a single, centralized database in order to remotely operate and control all of these and to plan future actions in the mine (World Economic Forum, 2017).

Confirming the above, Kurt Goldman, Director of Training at CAMIPER, School of Higher Studies, Mining Chamber of Peru, said that **the mining industry faces several challenges that it must overcome**, including the need to increase the productivity of its operations, reduce costs, use renewable energy sources, control its environmental impact and, above all, identify and control the inherent and emergent dangers to which thousands of workers are exposed. Clearly, all these challenges can be overcome by implementing the latest technology to achieve automated processes including the application of artificial intelligence (AI), given the extensive advantages of this technology in comparison, of course, with a less technological mode of operation or where, apparently, it is the human factor that reduces the efficiency of the system (Tiempo Minero, 2020).

In the same vein, Dan Miklovic, a researcher at LNS Research, believes that **the performance management of Assets 4.0 constitutes a radical change in the way in which a company performs maintenance**. The Industry 4.0-based model relies on cyber-physical systems to fundamentally change the way in which businesses operate. This uses a set of critical technologies (Miclovic, 2020):

- Industrial Internet of Things (IIoT): Integrated connectivity that allows extended useful product lives and product servitization.
- Big data analytics: Predictive analytics that leverage artificial intelligence (AI) and machine learning (ML) combined with modelling and simulation.
- Movement and position sensors to provide information anywhere and on any device.
- Augmented and/or virtual reality (AR/VR) for presenting information in an enhanced user experience and the use of digital twins.

Regarding operational safety, the Gerens mining company's management school (Gerens Escuela de Posgrado, 2017), clearly defines an automated environment where **remotely-controlled machines and smart ventilation** are both examples of the application of technology that have proved the most critical to improving the safety and efficiency of mines. These remote-control applications with multiple feedback sources help reduce numbers of staff in the most dangerous areas and at the most dangerous times. They also improve productivity by shortening the time between incidents and miners entering the area.

2.2.5 Energy

Energy is possibly the sector that is most forcefully engaged in the process of incorporating new circular economy and digitization models. This can be deduced from the strategies published by all the major energy companies, and it can also be confirmed by the publicly-stated opinions of its executives, as will be shown below.

From an analysis of these current strategies, it can be deduced that the l**ines of work set by companies in the energy sector are mainly built on three pillars:**

- Decarbonization, with the application of circular business models based on a renewables mix.
- The trend towards decentralization of production.
- The need for digitalization applicable to operation/maintenance processes and customer relations.

These are the three axes that define the competitive environment of the industry worldwide. In other words, renewable energy, less production in large power stations and active and informed customers will bring about changes to the distribution structure supported by a smarter grid that will make it possible to reduce transmission losses and apply energy-efficiency improvement strategies based on collaboration between the producer and the customer. These changes involve the introduction of new circular business models supported by digitalization and, critically, smart technology.

One of the main conclusions of the enerTIC Forum in respect of the impact of smart technology on the sector is that **the customer will be the central focus of the new energy business**, and that companies working in the sector understand that digital transformation is the means by which to achieve the goals that customers demand, that is, energy that is cheaper, high quality and sustainable (Mujer Emprendedora, 2018).

Furthermore, the move towards generating in smaller-scale plants involves self-consumption and this new role requires the automation of certain complex processes, due to the possibility open to customers of exchanging energy on the grid. Faced with this expected demand for self-consumption, companies in the electricity sector have a need to digitalize in order to support its management. Industry 4.0 will enable the introduction of new demand-oriented energy business models and of services provided to consumers to enable their real-time participation.

This can also be corroborated in the opinions of the leaders of the big energy companies as quoted in the PwC 14th Global Power & Utilities Survey (PwC

España, 2015), in which senior power and utility company executives in 70 companies and 52 different countries around the world evidenced their optimism regarding the evolution of the digitalized energy market.

Which areas will become important in coming years can be deduced from the responses given by the leaders of energy-sector companies.

Collaborative design of energy-efficiency models in cities and companies, and the management of generation distributed by themselves and support for generation distributed by third parties will be key variables to manage in order to respond to the expectations of the market. In this context, a new line of business based on the definition of infrastructure and the optimal producer/customer relationship model will come to the fore, transforming consultancy and service provision to achieve consumption efficiency into a crucial element of competitiveness in the sector.

According to these published opinions of leaders and the big companies' strategies, it can be deduced that the new paradigm of business model in the electricity industry is supported by customer/producer collaboration, for which the meeting place will be within the smart grid. **A grid that has all its assets, such as meters, substations and transformers, automated and digitalized** will enable consumers to make better decisions about their energy consumption while management of the operation and maintenance of the grid itself will become more efficient. This smart grid will support managing a dynamic relationship between producer and customer in order to efficiently marry supply and demand in real time. The end result will be increased security and quality of supply, together with reduced energy losses.

Another aspect where this collaboration between producer and customer will have an impact is that of the costs of investment in network infrastructure, since estimated energy-supply peaks will reduce, thanks to excellent demand management. Remote monitoring and control of energy production and consumption allows continuous supply & demand matching and a flattening of the demand curve, which has a direct impact on reducing maintenance costs and improving efficiency (reduced grid losses). This will then lead to a subsequent reduction in electricity costs due to more-precise and more-sensitive consumption.

Active, much better-informed consumers, a flattened demand curve and decentralized production supported by renewable technology will make management of energy systems more complex. Information technology, big data, the Internet of Things, robotics, drones and artificial intelligence are essential to support changes to the operational management and relationships models that are the main cause of the new paradigm.

The conclusion is that the new circular business models described above are critical to maintaining the competitiveness of the sector's businesses in the new market, and that it is only possible to support these models by means of major investments in digitalization and smart technology.

Another key aspect of energy management to consider is that of security of supply in a digitalized world; **cybersecurity** has to be part of any company's development strategy.

In addition, and, perhaps, **the key to the sector is that this is critical to national economies on account of its cross-cutting nature**, meaning that its effective management forms part of competitiveness for all the rest, as well as a decisive factor in the fight against climate change.

2.2.5 Waste management

According to the World Bank (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018), **if urgent measures are not taken, by 2050 global waste will increase 70% in comparison with current levels**. This will be through the rapid combined growth of cities and population. From this follows the key importance of this sector and the urgent need to apply circular business models. There is a major environmental problem that directly affects citizens' quality of life. Comprehensive digitalization of the entire value chain and citizens' participation in the whole recycling process is one of the great challenges in the sector.

The model for the digitalization of this service is similar to that of other sectors. The starting point is that of the **sensorization of assets**: trucks and containers are fitted with sensors, for their internet connections to be used in due course to analyse and connect the whole process for its more-efficient management using big data and artificial intelligence. To do this, sensors are placed on waste-collection vehicles and these are used to compile real data on the deposit, collection and management of urban waste. Sensors are also fitted to monitor waste containers and optimize waste collection. These will be wireless sensors placed in the containers to measure when they are full, helping to generate flexible emptying schedules and optimize collection routes. This resource will enable the collection company to better plan the use of its labour force and vehicles, leading to greater efficiency, increased productivity, reduced logistics costs and lower carbon emissions from vehicles.

Experiments have also been conducted whereby the containers know the personal identification of the user and, therefore, their use of the service. This will be used to determine precisely how much each citizen pays for waste collection.

According to leading companies in the industry, such as Ferrovial, **Industry 4.0 technologies are changing the design of the waste processing plants** of the future Their name should be changed to "materials production plants" and they should be based on three lines of action (Ferrovial, 2019):

- Flexibility: capacity to adapt to change in the composition and quantity of the materials to be processed.
- Safety: for this, it will be necessary to remotely control operations and prevent human contact with the waste.

- Comprehensiveness: capacity to recover 100% of the materials contained in the waste stream.

To meet the three criteria mentioned, there is no doubt that the plant will have to be completely connected. Internally, it will have to have real-time process control. Upstream, the plant will need advance notification of the waste due to arrive and downstream, it will need to constantly know the market demand and price for materials.

To adequately respond to the challenges described, it will be necessary to automate (robotize), sensorizing all assets: those in the collection process and those in the in-plant treatment process. This will require digitalization using cloud computing for the endless amount of data throughout the value chain, big data and artificial intelligence. The ensuing reduced operating costs and environmental impact will justify the necessary investment.

3. The benefits of applying models and disruptive technologies to circular economy initiatives

This section describes the benefits of applying models and disruptive technologies to circular economy initiatives identified in each country: Brazil, Chile, Mexico and Uruguay.

The starting point is the initiatives previous identified in Deliverable 2.4 of this project. All the initiatives have been considered, irrespective of their degree of maturation. In order for the country's most-interesting initiatives to be classed as circular, they were considered on the basis of their alignment with the principles of the circular economy defined in the previous deliverable, that is, whether they simultaneously possess the following characteristics: integrated consideration of the global value chain for evaluating their benefits of efficiency and environmental impact; the innovative incorporation of this consideration; and evidence of the sustainable perspective in their design. Another key aspect taken into account is their potential for scaling in the region or sector concerned. This variable will be decisive for the initiative's support from a social or national perspective.

Regarding business models and disruptive technologies, the circular business models presented in the previous section and applicable Industry 4.0 technologies identified in Deliverable 5.1 have been considered (see **Annex 1**).

Regarding the benefits considered, the following economic, social and environmental benefits derived from application of circular business models and disruptive technologies were taken into account:

- **Economic**, such as increasing competitiveness or offering greater security in the use of natural resources.
- **Social**, such as job creation and increasing the country's human capital.
- **Environmental**, including emissions reductions and climate-change mitigation, associated with the use of clean energy (circular supplies), increased efficiency in the use of material resources and minimizing organic waste that contributes to greenhouse-gas emissions.

The initiatives identified for each country will be presented below. They will begin with their description and go on to present a table setting out their alignment with circular models and their potential smart technology support.

3.1 Brazil

In the case of Brazil, initiatives were selected on the basis of the analysis contained in Deliverable 2.4 and the criteria given above. Account was also taken of the technological and industrial development challenges in Brazil. Comments have also been provided on the industrial sectors underlying some initiatives of a general nature, with the goal of identifying applicable Industry 4.0 technologies.

3.1.1 Initiatives considered

1. **Bioeconomy – Science, Technology and Innovation Plan 2018 (Plano de Ação em Ciência, Tecnologia e Inovação em Bioeconomia)**

This initiative is led by the Ministry of Science, Technology and Innovation (MCTI).

The Bioeconomy Science, Technology and Bioeconomy Innovation Action Plan (PACTI) has the goal of scientific, technological and innovative development to remove barriers and seize the business opportunities offered by the national bioeconomy. It is built around sustainable development in order to focus on securing social, economic and environmental benefits in an integrated manner.

The main features of PACTI are:

- The sustainable use of processes, the use of renewable biological resources and the conservation of biodiversity through replacement of fossil resources.
- The integration of initiatives related to water, food security and energy.
- The integration of initiatives for the development of bio-business and bio-products.
- Scientific and business excellence.
- Sustainable development and circular economy.

PACTI incorporates use of the following technologies:

- Technologies for converting biomass waste into bioenergy.
- Green chemistry.
- Genetic improvement.
- Biomimicry.
- Convergence of biotechnology, ICT and cognitive technologies.
- Automation and robotization of industrial biomass processes.

2. FINEP and FINEP *startup*

FINEP (Research and Projects Funder, Financiadora de Estudios y Proyectos) is part of MCTI and is the government agency for promoting innovative projects. It has had a pioneering role in Brazil in the funding of innovative circular-economy projects. Some examples of the projects supported by this institution follow:

- Braskem: polyethylene from natural sources.
- Sabesp: fertilizer from sewage-plant sludge.
- MPC: silica from rice husk.
- Mahle: design of parts for oil and fuel efficiency.
- B&A: fertilizer from alternative sources.
- Carbonífera Criciuma: sulphur products from mineral waste.
- Natura: development of natural aromatic ingredients.
- CTC: second-generation ethanol and new products from sugar cane.
- Geoenergética: biogas from biomass.

Within FINEP, particular mention should be made of FINEP *startup*, which has the goal of supporting innovation in start-up companies, covering the support and finance gap between the initial phases of innovation (accelerator programmes, angel investors and crowdfunding) and the final phases of innovation (Seed Money funds and Venture Capital and eventual launch onto capital markets).

3. FINEP – ERA-MIN 2

The aim of this consortium is to provide financial support by means of grants for transnational research, development and innovation projects jointly conducted by business and ICT (information and communication technologies) in the sectors of:

- **Non-energy and non-agricultural raw materials**, including the metals subsectors
- **Construction and industrial minerals**

These topics focus on the sourcing, production, consumption, reuse and recycling of raw materials in a circular economy.

4. National Confederation of Industry – Circular economy studies

The National Confederation of Industry (CNI) is bringing together state industry federations, industry associations and representatives of companies to assess the degree of national development in respect of the circular economy and to devise strategies to accelerate the transition to this new economic model for drafting proposals based on global practices and trends in this area.

5. Ministry of National Integration – National Integration Pathways

The Ministry of National Integration has established National Integration Pathways as a strategy for regional development and productive inclusion. The "Circular Economy Pathways" are one initiative within this programme that seeks to promote innovation, differentiation, competitiveness and profitability for its associated companies with regard to circular-economy products, services and business models. More specifically, it has addressed prospects for digital transformation, national policy on sanitation and solid waste, challenges in the urban sanitation services sector, reducing food waste, the circular economy in Brazilian industry, and no-waste construction.

6. RenovaBio

RenovaBio is a government policy that recognizes the strategic role of all biofuels (ethanol, biodiesel, biomethane, biokerosene, second generation, among others, in the Brazilian energy matrix in terms of their contribution to energy security, market predictability and greenhouse-gas-emissions mitigation in the fuels market. Through this initiative, biofuels allow an increasingly sustainable, competitive and secure energy supply. RenovaBio consists of three strategic axes: 1) Decarbonization objective; 2) Biofuels production certification; 3) Decarbonization credits (CBIO).

The goal of the initiative is to make a major contribution to meeting the Nationally Determined Contribution (NDC) under the Paris Agreement, to promote the expansion of the use of biofuels in the energy matrix in order to improve the supply of fuel and stability of the market at the same time as increasing energy efficiency and reducing greenhouse gas emissions in production and marketing.

7. Cetem Project (Urban Mining)

The object of this initiative is to leverage strategic partnerships between government, academia, technological centres and cooperatives in order to increase investments through the dissemination of knowledge, scientific advances and technology to generate social well-being.

8. CTI Renato Archer. REMATRONIC Project

This initiative is targeted at recovering strategic materials from electronic waste in order to increase cost efficiencies and reduce environmental impact. Its lines of work are: (1) recovery of strategic materials from circuit boards from electrical and electronic devices; (2) using bio-metallurgy and hydro-metallurgy to re-use metals such as gold, silver, copper and palladium; and (3) technology to separate heavy metals and proper waste management.

9. LICOBAT Project

Development of processes for the economically-viable recover of strategic materials (lithium and cobalt) from end-of-life lithium-ion batteries.

3.1.2 Circular business models, smart technology and potential benefits

There now follows a table showing the alignment of Brazilian initiatives with defined conceptual circular models and the technology potential of Industry 4.0.

Table 3. Circular business models, smart technology and potential benefits in Brazil
Source: Prepared by authors

Name and objectives of initiative	Focus and circular business model	Potential Industry 4.0 technologies	Potential benefits
Bioeconomy Sustainable agriculture; innovation in advanced agriculture: Precision agriculture. Green chemistry, genetic improvement, bioenergy and biomass	Reducing environmental impact through efficiency in use of resources, water and energy. Cost efficiency Business model: Circular provisioning and resource recovery	Sensors, Internet of Things, drones, comprehensive interconnection via cloud services, big data, artificial intelligence. Convergence of technologies listed above.	Adaptability of production process, optimization of crop rotation Efficient use of water, energy, fertilizers and plant health products
FINEP-startup Circular-economy innovation projects	Reducing environmental impact and cost efficiencies All business models possible, depending on pilot	Potential for application of all Industry 4.0 methodologies	Simultaneous cost efficiencies and reduced environmental impact
FINEPERAMIN 2 ICT development in mining companies, raw materials	Efficiency in the production process through improved maintenance programme and materials used Business model: circular provisioning	Internet of Things, big data, artificial intelligence, machine learning combined with simulation models, digital virtualization of assets. Blockchain, collaborative robotics	Optimization of maintenance costs, increased safety of activities, commercial excellence
Circular economy studies (CNI) Development of circular economy and Industry 4.0 innovation initiatives	All circular models	All those presented, according to sector and specific industry Connecting databases to share information; cybersecurity and Internet of Things	Joint development of circular economy initiatives and Industry 4.0
Circular economy pathways (Ministry of National Integration)	All circular models	All presented, depending on specific sector and industry	Development of joint circular-economy and Industry 4.0 initiatives
RenovaBio Contribute to Brazil NDC under Paris Agreement; promote expansion of biofuels in energy matrix	Offsetting emissions from oil distributors	Big data, Blockchain, cloud services and Internet of Things	Promoting biofuels in the national energy matrix
Cetem Project (Urban mining)	Boost strategic partnerships between government, academia and technology centres to increase investments	Big data, IoT, cybersecurity	Boost for collaborative investments in circular economy

	and mitigate investment risk. All circular-economy models		
CTI Renato Archer REMATRONIC Project	Recover strategic materials from electronic waste Business model: circular supply	Big data, sensors, robotics, IoT	Cost efficiencies and reduced environmental impact
LICOBAT Project	Economically-viable recovery of strategic materials from Li-ion batteries Business model: circular supply	Big data, sensors, robotics, IoT	Cost efficiencies and reduced environmental impact

The benefits from application of smart technology to the projects shown in the table above are detailed below.

- The application of smart technology to **sustainable agriculture** projects such as those promoted under the **Science, Technology and Bioeconomy Innovation Action Plan** generates significant production efficiencies, reduced environmental impact and improved quality of the products obtained. This is due to the increased flexibility/adaptability of the production process to the circumstances of the crops and the environmental characteristics of the plots. Likewise, sensorizing production will reduce the use of water, fertilizer and plant health products and improve the energy efficiency of facilities. It is also significant to take account of the reduced environmental impact inherent to precision agriculture.
- The benefits of initiatives, such as **FINEP-startup**, are key to the development of circular-economy and Industry 4.0 models. They provide essential motivation for entrepreneurs and will form the breeding ground for the cultural and paradigm change of the circular economy and Industry 4.0.
- The benefits of applying smart technology to mining projects, such as **FINEP-ERAMIN**, include the use of ICT to integrate assets, processes and people in a way that leads to reduced maintenance costs and safety improvements, in addition to ensuring the origin of goods through the use of Blockchain technology. The effects of including these technologies in the production process also include a high degree of improvement to the environmental impact inherent to mining. Taken together, all these positive effects become a reputational opportunity for companies. In other words, all this is suitable for communication to the relevant community, with positive effects on public perceptions. Transparency and integration of stakeholders' expectations are two benchmark principles of the circular economy.

- The smart technologies applicable to **studies of the circular economy (CNI) and circular economy pathways (Ministry of National Integration)** relate to the Internet of Things, cybersecurity and big data. With these technologies, it is possible to analyse and share the benefits and results of initiatives and enable consistent analysis by all actors, using homogeneous criteria and indicators. The positive impacts on improving efficiency and reducing environmental impacts need to be considered for each particular initiative. It is also important to take into account that this initiative may lead to different actors collaborating on new innovation projects, with the consequent implicit effect of scaling the circular economy.
- The smart technologies applicable to **RenovaBio** include: Big data for analysing data related to the configuration of the market; the Internet of Things to connect the different actors; cybersecurity; and even Blockchain, to enable precisely-tracked market interactions.
- The **Cetem Project – Urban Mining**, represents the realization of the public-private collaboration that is fundamental to the development of Industry 4.0 technologies and circular-economy business models. Government leadership in respect of the example it sets in the management of its services and coordination of national competitiveness strategies in the sectors and regions is something that has to be seen in flexible and progressive strategies.
- Lastly, the **CTI Renato Archer projects, REMATRONIC and LICOBAT**, are similar in nature and have the benefits in common of simultaneous reduced costs and environmental impact

3.2 Chile

Initiatives have been selected on the basis of the analysis contained in Deliverable 2.4 and the criteria mentioned above. In the case of Chile, it was chosen to analyse the most-interesting innovation projects from the viewpoint of integration of the circular economy and Industry 4.0, related at the same time to key industrial sectors of the Chilean economy.

3.2.1 Initiatives considered

1. **Development of the recycling logistics system: "Smart Recycling Logistic System"**

Smart Recycling Logistic System is a platform for optimizing the logistics of recycling. It consists of an application that determines the optimal route for collecting and tracing waste from source to final disposal and a mobile modular system that reduces the volume of waste *in situ*. Working in this way adds value to industries subject to collection targets, taking maximum advantage of vehicles' load capacity and reducing logistics costs and the system's carbon footprint.

2. **Manufacture of wearing parts for the mining industry**

Processing copper ores causes huge wear on equipment, hence the constant need to seek metal alloys with better performance and abrasion resistance. The purpose of this is to reduce the frequency of plant shutdowns for replacing worn parts and also to reduce the large amounts of scrap metal currently generated and constantly accumulated in mining areas.

3. **Electronic waste recovery: Chile's potential for urban mining**

This project seeks to evaluate, develop and determine a process for recovering precious metals from printed circuit boards, through a specific pyrolysis process. The necessary materials will be provided by the beneficiary, which will also supply the information and results obtained internationally with the goal of comparing concentrations obtained using the specific process to be used with the non-specific process used in the rest of the world.

4. **Using the IoT for reducing packaging and inventory control of automotive chemicals**

Creating a bulk distribution system for the main chemicals used in the automotive market. For this will be built: (i) a structure allowing the safe transportation of chemicals; (ii) a system to propel and control the flow of the products dispensed; (iii) a modular storage system to receive the liquids; and (iv) an IoT stock-monitoring system available to both the supplier and users via a web platform.

5. **Smart Yeast: Reuse of discarded yeast**

Fermented yeasts used for beer production are one of the biggest waste products of the brewing industry, generating 42,000 tonnes of waste per year in Chile, none of which is recycled. This project consists of a method for producing yeast extract from waste without the addition of salt or any other chemical compound. This is achieved by using predatory yeasts and/or pure enzymes capable of hydrolyzing yeast waste to obtain natural, nutritious extracts.

6. Agro-industrial waste recovery

This project consists of the application of a circular economy model that seeks to use vermicomposting to remanufacture and reuse organic waste produced by Biofresco. The company's separation of waste at source will enable the development of a vermicompost with particular physical and chemical characteristics for obtaining a specific substrate for sustainable mushroom cultivation, thus reducing its production costs.

7. AgroWaste2Energy

The aim here is to prototype a process for the continuous automated extraction of pectin and hydroxytyrosol and energy generation using the anaerobic digestion of waste apple and pomace from the apple industry and alperujo, which is a by-product of olive oil production. This offers an attractive solution from the economic point of view for these waste products.

8. Carbon black from the pyrolysis of tyres

The tyre pyrolysis process generates three by-products: gas, metal and carbon black. The gas produced undergoes further treatment within the circular economy, being distilled to produce fuel, and the metal (steel) is recovered and sold. There is, however, no market in Chile for the direct sale of carbon black. Furthermore, the complexity of the process means that it is not of a constant quality, due to the different qualities of tyres entering the pyrolysis reactor. This initiative seeks to generate an analysis of the most-promising alternatives for carbon black, leading to a productive use for 5,700 kg of it per week, or 68,400 kg per year, for which there is currently no sales opportunity.

9. Bioplastics recycler

The main problem is an environmental one, as everyone and everything, men, women, children, adults and even flora and fauna are affected by plastics pollution. The solution lies in the correct use of bioplastics, which do not have the harmful consequences of plastic for the environment and human health. The world trend is for these products to increase year on year; according to europeanbioplastic.org, the world bioplastics market will grow by 20% in the period from 2017 to 2022.

The main bioplastics include biobased (not biodegradable) and biodegradable plastics (PHA, PBS, PLA). It is the last of these, PLA biopolymer, that Compobottle sells in its bottles, bags, glasses, films, and cutlery, among others. However, all these products must be accompanied by a correct "end of life" for biodegradability (recycling, composting or biodigesting). That is why

Compobottle decided to take charge of product ends of life and enhance the bioplastics circular economy. It decided to throw its weight behind the lowest-cost, easiest and industrially scalable option: recycling. It was from there that the idea was born of reusing bioplastics with a recycling machine that creates filament for 3D printing.

3.2.2 Circular business models, smart technology and potential benefits

This report will next present Chile's circular economy initiatives in a table that describes each initiative in terms of its main objectives, implicit circular business model, potentially-applicable smart technologies and the expected benefits of each application.

Table 4. Circular business models, smart technologies and potential benefits in Chile
Source: Prepared by authors

Name and objectives of initiative	Focus and circular business model	Potential Industry 4.0 technologies	Potential benefits
Recycling logistics system Optimization of logistics for waste collection	Optimize the logistics and processing of waste. Increasing efficiency and reducing environmental impact Business model: resource recovery	Big data, sensors, Internet of Things, cloud services route optimization software and robotics	Reduced environmental impact and improved efficiency, connected throughout the value chain. Enabling the creation of fully-connected remotely-operated and flexible "materials production" plants, depending on the type of waste
Manufacture of wearing parts for the mining industry Mining production process	Cost efficiency and environmental improvement of the production process Business model: circular provisioning	Internet of Things, big data, artificial intelligence, machine learning combined with simulation models, digital virtualization of assets. Blockchain, collaborative robotics and sensors	Given the asset intensity of the mining industry, a key variable for the efficiency of the production process is the optimization of maintenance, leading to reduced costs and environmental impact
Electronic waste recovery Using pyrolysis for the recovery of precious metals	Closing the circle: materials to waste, waste to raw material Business model: resource recovery	The dual systems of artificial intelligence and advanced robotics to improve waste selection capacity, obtaining a greater number of materials and of better quality. Big data, Internet of Things, cloud services and Blockchain, all in combination	Process efficiency and reduced environmental impact
Reducing packaging for automotive chemicals	Production and distribution efficiency and reduced environmental impact	Internet of Things, robotics, data processing, smart software and sensors, from suppliers to	Integration of the whole value chain, generating efficiency while at the same time

Reduced packaging and inventory-control optimization	Business model: circular provisioning	customers, to be able to smartly predict, control, plan and distribute, generating greater value along the entire chain	reducing environmental impact

Table 4 Circular business models, smart technologies and potential benefits in Chile
Source: Prepared by authors (continued)

Name and objectives of initiative	Focus and circular business model	Potential Industry 4.0 technologies	Potential benefits
Bioplastics recycler Recycling biodegradable plastic	Recycling: biodegradable bioplastics to obtain raw material for 3D printers Business model: resource recovery	Internet of Things, cloud services, big data, sensors and robots	Integration of the whole value chain, generating efficiency while at the same time reducing environmental impact
Smart Yeast Creation of a new product using waste from the beer industry	Upcycling: starting from waste from the beer industry, generate yeast extract, a new product used as a flavouring Business model: resource recovery	Internet of Things, cloud services, big data, sensors and robots	Reduced environmental impact and improved efficiency, connected throughout the value chain. Maintaining the value of resources, reducing raw materials inputs
Agro-industrial waste recovery Use of vermicomposting to generate substrate for growing mushrooms	Recycling: Using worms to process organic fruit and vegetable waste Business model: recovery of the value of resources	Internet of Things, cloud services, big data, sensors and robots	Reduced environmental impact and improved efficiency, connected throughout the value chain. Maintaining the value of resources, reducing raw materials inputs
Agrowaste2Energy Using waste from the apple and olive oil industries for energy	Upcycling: Using waste from the apple and olive oil industries to generate raw material for power generation Business model: recovery of the value of resources	Internet of Things, cloud services, big data, sensors and robots	Reduced environmental impact and improved efficiency, connected throughout the value chain. Maintaining the value of resources, reducing raw materials inputs
Carbon black from tyre pyrolysis Tyre materials waste recovery	Recycling: Use of the liquid and gases resulting from pyrolysis Circular model: resource recovery	Internet of Things, cloud services, big data, sensors and robots	Reduced environmental impact and improved efficiency, connected throughout the value chain. Maintaining the value of resources, reducing raw materials inputs

The benefits of the application of smart technology to the projects shown in the table above are detailed below.

- The use of smart technology in the **Recycling Logistics System** consists of the sensorization of the components used for collection (containers and vehicles) for their integrated connection, resulting in excellent management of the entire process. This will simultaneously provide reductions to environmental impact and associated financial costs. The technologies used are sensors on collection assets, data integration over the Internet and data management using big data and artificial intelligence.
- The **Manufacture of Wearing Parts for the Mining Industry** initiative has to go hand in hand with application of the smart technologies presented in the previous chapter. The ability to integrate assets, processes and persons in mining leads to reduced maintenance costs and enhanced safety, while also ensuring precise tracking of the origin of goods.
- The main smart technologies applicable to the **Electronic Waste Recovery Initiative** (precious metals recovery using pyrolysis) include systems combining artificial intelligence and advanced robotics to improve waste selection capacity. The combined use of big data, Internet of Things, cloud services and Blockchain also has high potential. Their application will ensure that information supplied is accurate, in order to compare the concentrations obtained using the specific process with those obtained from the traditional non-specific process used elsewhere in the world. The cost-efficiency benefits and reduced environmental impact are evident.
- The smart technologies applicable to the **Reducing Packaging for Automotive Chemicals** project relate to robotics for the handling of items in warehouses, the sensorization of assets (containers and inventory), the use of the internet for information transfer and the combined use of big data and artificial intelligence in order to simultaneously optimize distribution routes and stock management. This will produce a benefit in terms of management costs and reduced environmental impact through the efficiency of routes and reduced use of raw materials.
- The smart technologies applicable to the **Bioplastics Recycler**, the **Smart Yeast** project and the **Agro-Industrial Waste Recovery** project (vermicomposting) involve the sensorization of containers and inventory, use of the internet to transfer this information and analyse it through the combined used of big data and artificial intelligence. The benefits simultaneously relate to cost efficiency and reduced environmental impact.
- The Industry 4.0 technologies applicable to the **Agrowaste2energy** project are the same as those mentioned for the Recycling Logistics System and the benefits relate to simultaneously-achieved efficiency gains and reduced environmental impact.

- The smart technologies applicable to the **Tyre Pyrolysis Carbon Black** project include the sensorization of the assets used (stores, containers, etc.), the commercial management of clients through big data and the integrated management of the entire process via artificial intelligence. This would simultaneously result in reduced costs and environmental impact.

3.3 Mexico

Initiatives have been selected on the basis of the analysis contained in Deliverable 2.4 and the criteria mentioned above. Account was also taken of the technological and industrial development challenges in Mexico. Comments have also been provided on the industrial sectors underlying some initiatives of a general nature, with the goal of aligning the Industry 4.0 guidelines with these.

3.3.1 Initiatives considered

1. Materials recovery platform

The aim of this initiative is to create a materials market in the iron and steel industry that will increase their value in the various stages and cycles of use.

Current regulations impose a limitation on the use and reuse of metallic materials, as they can only be classified as raw (virgin) material or waste (scrap). This does not permit the creation of a materials market that differentiates for types of application and levels of quality, for those that would fit into such categories.

2. Circular economy learning network

Based on previous work by PROFEFA in the Programme for Environmental Leadership and Competitiveness, it is hoped to be able to create a Circular Economy Learning Network, where anchor companies encourage the SMEs associated with their production chain to apply the different learning in this field.

The aim of the initiative is to make production chains circular, through knowledge networks where large corporations guide SMEs.

3. GIZ Corporation's FELICITY Project (Financing Energy for Low-carbon Investment – Cities Advisory Facility)

This initiative aims to generate energy from municipal solid waste (MSW).

Mexico generates 103,000 tonnes of MSW every day, of which 9.63% is recycled.

The tipping of this waste in landfill sites and its handling contributes 4.6% of the country's GHG emissions.

The pilot project, to generate power from MSW, is in the municipality of Naucalpan (population: 872,000), in the State of Mexico.

It is noteworthy that there is also energy from MSW in the city of Aguascalientes where 2.7 MW are generated for vehicle manufacture in the Nissan complex, and in Monterrey, where the power generated covers 45% of the energy needed for street lighting and the Metro transport system (BENLESA, 2003).

4. Specification for the Carbon Market

The Ministry of the Environment and Natural Resources (SEMARNAT) will progressively and gradually establish an Emissions Trading System with the aim of promoting emissions reductions in the participating sectors. Similarly, it is identified in the transitional articles of the General Climate-Change Act that Mexico agrees to an unconditional 22% reduction in its GHG emissions by 2030, compared to the baseline.

In October 2019, the preliminary specifications for the Emissions Trading System Trial Programme were published, with the participation of various actors from the industrial sector including the National Chemical Industry Association (ANIQ). The trial phase began on 1 January 2020 and will conclude on 31 December 2021.

5. Opportunities for symbiosis in the tequila industry

This project is based on life-cycle study that identified alternative uses for agave bagasse, which were sold to other companies in the sector.

The actions taken include redesigning containers and packaging, capturing the CO2 from fermentation for reuse in other sectors, using agave leaves as energy source, and added-value products (bioplastics, furniture, food and pharmaceuticals).

6. Recycling PET bottles

This initiative, led by Mexican company PetStar, recycles 84,000 tonnes of PET bottles per year, producing 52,000 tonnes of recycled food-grade PET resin and avoiding the production of 108,000 tonnes of CO_2e from the production of virgin resin. Given its scale, this initiative is an important step in the transition to the circular economy (Petstar, 2019).

7. Cement industry

The Cemex company, which produces cement, concrete, aggregates and other construction materials, initiated a project to gather data from its plants worldwide, to turn the data into learning with tangible benefits. Using IoT technologies, the system is able to collect, analyse, display and share large amounts of historical data from various sources for use by persons and operations systems. The company succeeded in taking control of its operations, predicting possible failures and optimizing processes, from anywhere and in real time (Reportero Industrial, 2019).

8. Automotive industry

The Ford company is incorporating Technology 4.0 into the manufacture of its products, such 3D prototype printing in the laboratory of the Engine Plant in Chihuahua, Mexico, and the use of an exoskeleton for unit assembly in its Cuautitlán plant. Similarly, in 2018, the Hermosillo and Cuautitlán plants were equipped with exoskeletons to reduce the physical exertion, injuries or discomfort of its staff during vehicle assembly (Ford, 2018) (Ford, 2018).

Volkswagen Mexico is currently implementing a Technology 4.0 transformation that began with the development of staff skills and continued with the establishment of efficiency standards to facilitate the rapid adoption of new technologies.

By February 2020, some 800 robots had already been incorporated into the body-production shop, as well as a mechanism whereby an operator and a robot arm work together to carry out processes, the first of these being painting tasks (Paralelo19.mx, 2020).

9. Study into the carbon footprint of the paper and cellulose industry

This study, based on a life-cycle assessment, determines the contribution of the sector to reducing greenhouse-gas emissions, while at the same time providing a tool for the evaluation of results and scenarios in corporate policies, such as improving energy efficiency, the transition to energy sources with lower environmental impact, the treatment and recycling of water, the establishment of commercial forest plantations and increasing the percentage of recycled raw materials, since 54% of the paper and cardboard consumed in Mexico is not recycled (Cámara Nacional de las Industrias de la Celulosa y del Papel, 2020).

3.3.2 Circular business model approaches, smart technologies and potential benefits

This report will next present Mexico's circular economy initiatives in a table that describes each initiative in terms of its main objectives, implicit circular business model, potentially-applicable smart technologies and the expected benefits of each application.

Table 5. Circular business models, smart technologies and potential benefits in Mexico
Source: Prepared by authors

Name and objectives	Circular business models approach	Potential Industry 4.0 technologies	Potential benefits
Metallic materials recovery platform Create a market for materials that increases their value and usage cycles in relation to their applications and quality levels	Recycling: Use of raw materials and scrap in accordance with the use and quality required Business model: resource recovery in the metallic raw materials and scrap market	Internet of Things, cloud services, sensors, big data, Blockchain and cybersecurity	Integration of value chains to increase their efficiency, reduction of GHG emissions and preserving the value of resources
Circular economy learning network Promote and guide SMEs forward on the basis of the experience of larger companies.	Various business models: industrial symbiosis, recycling, remanufacture, reuse, sharing assets, and also innovative purchasing, whereby the functional specifications of the trailblazing companies are replaced by giving suppliers a definition of needs and suppliers combine these to offer an excellent response.	Internet of Things, cloud services, big data, Blockchain and cybersecurity	Expansion of digitalization and CE models in the regions
Felicity project Using MSW to generate energy	Business model: resource recovery	Big data, Internet of Things, sensors, cloud services and robotics	Reductions in environmental impact and GHG emissions
Specifications for the emissions market Creation of an emissions market	Provides momentum for all circular business models	Big data, Internet of Things, sensors, cloud services	Reduced GHG emissions and compliance with international agreements
Industrial symbiosis in the tequila industry Reduced use of fertilizers, water and energy and development of new markets for bagasse	Business model: recovery of the value of resources and circular provisioning	Big data, Blockchain, cloud services, sensors, smart software and robotics	Value-chain integration, process efficiency and reduced environmental impact

PET bottle recycling Recycling PET bottles to produce recycled resin	Business model: recovery of the value of resources	Big data, Internet of Things, sensors, cloud services and robotics	Reduced consumption of raw materials, reduced GHG emissions
Operational excellence in the cement industry Analysis of operational data, remoted optimizing of production process	Business model: recovery of the value of resources and circular supplies	Big data, Internet of Things, sensors, cloud services and robotics	Reduced consumption of raw materials, reduced GHG emissions
Automotive industry 3D printing, training and robotization	Business model: recovery of the value of resources, circular supplies; potential for product life-cycle extension	Big data, Internet of Things, sensors, cloud services and robotics	Reduced consumption of raw materials, energy efficiency and reduced GHG emissions
Study into carbon footprint of paper and cellulose industry Knowledge of life-cycle environmental footprint	Business model: the potential of this model can be directed towards development of all circular business models described above	Big data, Internet of Things, artificial intelligence	Becomes the starting point for the development of any type of circular business model, with their associated potential benefits in terms of energy and reduced environmental impact

The benefits from application of smart technology to the projects shown in the table above are detailed below.

- The use of smart technologies on the **Materials Recovery Platform** includes the use of big data, cloud computing, artificial intelligence and cybersecurity. The process consists of sharing information from various actors, assessing it, and understanding the reasons for the variability of the pricing and sale of the product. The benefit that it will generate is the opportunity to reuse the raw material while constantly maintaining its value. Cost-efficiency benefits and reduced environmental impact are inherent to this initiative.
- The smart technologies applicable to the **Circular Economy Learning Network** are the combined use of big data, Internet, cybersecurity and artificial intelligence. Its goal is to guide and promote SMEs on the basis of the experience of larger companies. In short, the plan is to create a triple-helix collaborative environment incorporating government, business and knowledge. This entails a need to exchange best practice and launch collaborative pilot projects. The data to be controlled are, basically, the project-progress indicators and the results achieved through their application. In addition, these data need to be shared by all actors, which will provide a homogeneous context of knowledge where it will be possible to position innovation as an integrated tool in businesses' strategies.

- The smart technologies applicable to the **Felicity Energy from MSW** project are oriented towards helping waste companies to better manage the collection and recycling of all types of waste. With the help of the digital trends described above, such as big data, smart sensors and mobile applications, many solutions have been created that could revolutionize the field of waste management, with the primary objective of optimizing local management of waste, improving citizens' quality of life and encouraging public participation in recycling processes. These initiatives will have a simultaneous direct impact on improving the efficiency of activities and reducing their environmental impact.

- The smart technologies applicable to the **Emissions Market Specification** project will be a combination of big data, Internet, artificial intelligence, cloud computing, and Blockchain, with the goal of creating a transparent and efficient market. Its benefits will take the form of the possibility of reducing industrial emissions at the pace established by the international commitments accepted by Mexico.

- The smart technologies applied to the **Industrial Symbiosis in the Tequila Industry** project will be focused around the Internet and big data, which will be used to facilitate information sharing between different actors on the availability and price of different raw materials. Regarding the prices for the collection and storage of raw material, the technologies mentioned as part of recycling initiatives will be used, basically around the sensorization of assets and warehouses, and robotized handling. Simultaneous efficiency improvements and environmental impact reductions are inherent to this initiative.

- The use of Technologies 4.0 in the **recycling of PET bottles** to obtain PET resins may involve the use of big data, cloud computing, artificial intelligence, sensorization and robotization for collection, storage and processing processes. In this respect, the consequent savings in raw materials and reductions in GHG emissions should be noted.

- The application of smart technologies to the **cement industry project** to gather data from its plants around the world and turn the data into knowledge with tangible benefits fundamentally consists of implementing the technologies of IoT, bit data, artificial intelligence, cloud computing and cybersecurity. The system has capacity to collect, analyse, display and share large quantities of historic data from various sources for the use of persons and operational systems. The benefit of the project is related to the improvement of the process, both in its operation and maintenance. The possibility under the project of using the system remotely and in real time will bring a noteworthy improvement to the flexibility of the production process.

- The Technologies 4.0 applicable to the **projects under way in the automotive sector** in the manufacture of its products, its use of 3D printing for prototyping and process robotization will increase the capacity to develop eco-designed products for incorporation into the production process, such as increased efficiency through robotization. The technologies in question will be a combination of big data, Internet, artificial intelligence, cloud computing, 3D printing and robotization, in order to create a production process that is both more efficient and lower in its environmental impact.

- The smart technologies applicable to the **project to calculate the environmental footprint in the paper and cellulose sector** are primarily big data, artificial intelligence, IoT, cloud computing and cybersecurity. The goal of this initiative is to identify opportunities to reuse commodities, and to reduce the environmental impact of its operations. It is a starting point for the design of innovation projects involving Technology 4.0 to develop circular business models. Its implementation, using a homogeneous methodology in different companies in the sector, has the potential to develop collaborative projects in these companies in order to improve efficiency while reducing environmental impact, and also to provide an opportunity to share best practice between companies.

3.4 Uruguay

Initiatives have been selected on the basis of the analysis contained in Deliverable 2.4 and the criteria mentioned above. Account was also taken of the technological and industrial development challenges in Uruguay. Comments have also been provided on the industrial sectors underlying some initiatives, with the goal of aligning the Industry 4.0 guidelines with these.

3.4.1 Initiatives considered

1. **Biovalor / 2017**

This project seeks to promote waste recovery technologies to reduce greenhouse gas emissions.

The Uruguayan Government, together with UNIDO, is conducting this project with the goal of supporting the transition from a linear model to a circular one, understanding that this process is necessary for an effective shift towards sustainable forms of production and consumption.

2. **Plan Junta Lámparas**

This plan is for the collection of worn-out compact fluorescent lamps, which the public leave in containers located in premises that are part of the scheme. The lamps will then be taken to a treatment plant for processing using a system approved by the environment authority.

3. **Waste recovery from electrical and electronic goods (Antel Integra)**

Unused information technology equipment will be used, donated by companies and individuals.

Antel has a recycling centre for classifying, disassembling, cleaning and recycling the equipment received. In this centre, complete computers will be assembled with the minimum hardware requirements and a light freeware installation.

The project aim is to collaborate, mainly with lower-income households, by providing them with a recycled PC with free software and Internet access.

4. **National Energy-Efficiency Plan**

The Plan includes general tools applicable to all sectors, and sectoral tools aimed at a specific target audience based on its consumption characteristics.

Recycling within the building industry to produce or reuse materials necessary for the construction of structures. The Plan contains a range of instruments to achieve an energy-savings target of 1,690 ktoe in the period 2015-2024.

5. **Circularity of dairy nutrients**

Deepen the potential for the circularity of nutrients in dairy establishments.

Improvement, monitoring and evaluation of waste and effluents management in five demonstration units of the national tertiary education system.

6. El Cerro Industrial Technology Park: Project to recover its waste

The El Cerro Industrial Technology Park (PTIC) is gradually implementing its waste management.
Currently, this management includes the collection of non-recyclable waste under a service agreement with Montevideo City Council and the collection of recyclable waste, such as scrap metal, cardboard and paper. Recyclables are delivered to companies for recycling. The principle of continuous improvement is affirmed in waste management, and in all other environmental aspects.

The project goal is for the PTIC to have its own waste-sorting plant.

7. MOVES project

Concrete actions to promote public transport, non-motorized modes of transport and the use of electric vehicles.

The aim of the project is to promote effective transition towards a Uruguayan urban mobility model that is inclusive, efficient and low-carbon.

8. Electric vehicle charging stations

In 2017, the project began to link the roads of Uruguay, in every *departamento* with a range of vehicle charging points.

The aim of the project is to provide Uruguay with infrastructure for the expansion of electric transport.

3.4.2 Circular business model approaches, smart technologies and potential benefits

This report will next present Uruguay's circular economy initiatives in a table that describes each initiative in terms of its main objectives, implicit circular business model, potentially-applicable smart technologies and the expected benefits of each application.

Table 6. Circular business models, smart technologies and potential benefits in Uruguay
Source: Prepared by authors

Name and objectives	Circular business models approach	Potential Industry 4.0 technologies	Potential benefits
Biovalor Optimization of waste recovery from a circular perspective	Business models: resource recovery, circular provisioning, product-life extension	IoT, cloud services, smart software and sensors, big data, robotics and artificial intelligence. Smart containers, anaerobic digestion to generate biogas and biogas and biofertilizer, processing waste for use as soil improvers, catalytic depolymerization for generation of synthetic diesel fuel, water treatment for fertigation, combustion for steam or energy, and gasification gas generation. Treatment of dairy and meat industry waste for use as soil improvers	Potential to create materials recovery plants: Flexible in their treatment processes, safe and able to recover 100% of waste. Reducing environmental impact, integrating the value chain and generating efficiency
Plan Junta Lámparas Management of end-of-life compact fluorescent lamps	Business model: recovery of the value of resources; product life extension.	Big data, Internet of Things, robotics, smart containers, cloud services, low-environmental-impact collection vehicles	Value-chain integration, efficiency and reduced environmental impact
Waste recovery from electrical and electronic goods (Antel Integra) Provide more opportunities to access information technology and the Internet	All circular business models.	Big data, Internet of Things, robotics, smart containers, cloud services, low-environmental-impact collection vehicles	Promoting the Internet, reducing environmental impact

Table 6 Circular business models, smart technologies and potential benefits in Uruguay (continued)
Source: Prepared by authors

Name and objectives	Circular business models approach	Potential Industry 4.0 technologies	Potential benefits
National Energy-Efficiency Plan Promote energy efficiency in all sectors	All circular business models	Big data, Internet of Things, smart software, artificial intelligence and sensor connection	Consumption energy efficiency
Circularity of dairy nutrients Deepen the potential for the circularity of nutrients in dairy establishments.	Business model: circular provisioning and resource recovery	Robotics, sensors linked to smart software and Internet of Things	Reduced environmental impact
El Cerro Industrial Park: waste recovery Create a waste sorting plant.	Business model: circular provisioning and resource recovery	Robotics, big data, Internet of Things, sensors, artificial intelligence	Value-chain integration and reduced environmental impact
MOVES project Sustainable mobility	Business model: circular provisioning	Big data, smart sensor-connected software and Internet of Things	Generation of automated computerized urban public-transport systems
Electric vehicle charging stations Sustainable mobility	Business model: circular provisioning Given its circular nature; this project has great potential to use ecodesign in the physical structure of the charging point	Big data, sensors, smart software	Promoting electric cars

The benefits from application of smart technology to the projects shown in the table above are detailed below.

- As explained for other waste-management projects, such as **Biovalor, Plan Junta Lámparas, Antel Integra and El Cerro Industrial Park**, there is great potential for the integration of smart technology into every process, from collection, transport and logistics through to final processing in treatment plants. Smart containers, big data, IoT and artificial intelligence (AI) for data transmission and management, in-plant robotics in waste processing and maintenance, and the possibility of using drones for monitoring landfill sites. The goal is to create materials-production plants with flexible processes in line with the composition of the materials treated and that are safe for process and maintenance workers and comprehensive in terms of their capacity to recover all materials. The cost-efficiency benefits and reduced environmental impact are evident.

- Creation of the **National Energy-Efficiency Plan** requires in-depth knowledge of the various sectors' assets and consumptions; having consistent criteria for the identification of assets to be taken into account; defining consistent calculation criteria indicators; designing projects for implementation of working guidelines in each sector; general knowledge and coordination of implementation of the pilot projects; and sharing experiences of work between the different sectors. The potential for application of Industry 4.0 technology to development of the plan includes the combination of big data, cloud computing, artificial intelligence, cybersecurity and the Internet. The ultimate goal is to create a momentum of continuously improving public-private collaboration. The cost-efficiency benefits and reduced environmental impact are evident.
- The technologies that could potentially be applied in the **Dairy Nutrient Circularity Initiative** are based on the automation of product quality and safety processes; robotized palletization and packaging; and digitalization of businesses' commercial management and product traceability throughout the companies' various production stages, including storage and logistics. These are starting to see the expansion of Blockchain, sensors, and software to control effluents, fertilizers and soil quality. Their common goal is to generate efficiency, product safety and hygiene, higher quality and reduced environmental impact.
- The **MOVES Project**, which takes the smart city concept as its starting point, essentially requires the mass digitization of mobility. The technologies to be combined are: sensors in public roads and means of transport providing real-time information on the situation, status and availability of the service; the Internet; big data; and artificial intelligence managed via comprehensive platforms with the capacity to analyse the entire integrated process of citizen-mobility service-availability, in order to offer the public efficient and practical services. This whole new concept of mobility will bring with it considerable savings in energy costs and will reduce environmental impact.

- The aspect with the greatest potential for the Electric Vehicle Charging Stations project will be the incorporation of ecodesign technologies in the manufacturing process of the assets to be installed. As a methodology, ecodesign incorporates the environmental variable into the design of products with the aim of generating more-competitive manufacturing processes, through the inclusion of that variable in the product's quality requirements, connecting the product in this way with the customer's expectations and the company's requirement for return on investment.

4. Conclusions

4.1 Preliminary remarks

Prior to presenting the conclusions regarding the specific benefits of the initiatives analysed, it is considered relevant to highlight a number of previous aspects that link this document with document 5.1, thus framing both documents within the same line of discursive analysis.

When one considers the initiatives ongoing in the different countries, one can conclude that **they all contain a commitment to the circular economy and Industry 4.0**, since they have a potential for simultaneous economic and environmental benefits and also have potential to become the basis for scaling the circular economy and Industry 4.0 in each country.

One important prior aspect to note ahead of effective implementation of these initiatives is the need to take account of the **resistance to change** that has characterized every cultural transformation in the development of advanced-technology projects at the heart of circular-economy models. Implementation of circular-economy models supported by smart technology involve major changes to the ways of understanding relationships with stakeholders and the internal organization of work on processes. One of these important changes to consider is the evidence that **implementation of advanced technology involves designing efficient collaborative processes** between companies' internal departments, between different companies (in principle, competitors) and with government and the world of knowledge. This is because the risk of innovating, due to the high investments required, has to be mitigated by cooperating with the other stakeholders in the value chain, with government and with the world of knowledge, all at the same time.

There are also **regulatory, organizational and market barriers** that must be identified in advance and analysed in order to define a strategy for mitigating the risk of implementation. The main barriers to implementation of initiatives of the type analysed, and which have been deduced from the sources of information used to prepare this document can be summarized as the following (many of them also have express support in the indicators used in Deliverable 5.1):

- The necessary investment costs
- The ability to access personnel trained in these technologies
- The structure and organizational culture of organizations
- The country's telecommunications infrastructure
- A lack of funding and/or credit lines
- Management models unable to reflect the value of return on investment

- Difficulties in integrating the new software into companies' proprietary systems
- The effectiveness of existing regulation

Another prior aspect to highlight for facilitating and encouraging implementation of these measures in each country, and which would enhance their synergies to secure overall benefits, would be the desirability of setting out **an overarching circular economy and Industry 4.0 strategy for each country**. This strategy would have shared objectives and, aligned with these, public-, industrial- and regional-sector initiatives. This would lead to synergies between the different initiatives and an increased image of the entire collective effort made, based on the transparency of the global project encompassing all the initiatives. Development of this overarching strategy needs to be **supported by a public organizational structure**. This would provide national coordination for the definition and implementation of priority initiatives and would be the point of convergence between government requirements in respect of international commitments and national competitivity strategy, on the one hand, and support for industrial and regional sectors based on circular innovation and Industry 4.0 on the other.

One of the main technological challenges in all the countries is the basic need, prior to the development of all the specific initiatives, to consolidate the **development of telecommunication technologies systems**, extending them and increasing their connection capacity, as they are the means by which progress is made on the implementation of Industry 4.0. This measure underpins the development of all the initiatives presented and deficiencies here would lead to difficulties in their development.

4.2 Industry 4.0 technologies applicable to the sector

The main technological challenges for the sectors under consideration are mentioned below:

- **Agro-food industry:** in this sector, the concept of smart farms is visualized. The general trend is towards sustainable production processes. This industry is using GPS services, M2M technology and IoT aligned with sensors and big data to optimize crop yields while reducing production inputs: water, energy, fertilizers and pesticides, and waste. This requires that production be monitored, from predicting yields, monitoring the health of the crop and its needs through to recovery of the land for optimized crop rotation. For this, data on the soil, telemetry, smart software, big data/IoT and cloud services are needed.
- **Dairy sector:** Technologies for the partial automation of processes associated with quality control and product safety, with sensors and cloud platforms.
    - Full automation of production processes.

- Robotization of partial or isolated processes.
- Technologies based on the digital domain, for firms' commercial management tasks and for ensuring the traceability of products and during the company's various production stages, including storage and logistics.
- Systems, sensors and control software for effluents, fertilizers and soil quality.

- **Mining sector:** In this sector, which is especially important in Chile and Mexico, the use of smart technology is crucial to improve the safety of persons and for the maintenance of heavy machinery, remote operation of production, energy consumption of assets in accordance with operating conditions and cost reductions of supply through to the final purchaser using Blockchain. In this sector, consolidating a combination of sensors, IoT, big data and cloud would pave the way towards artificial intelligence algorithms that would anticipate hazards, as well as robotics and sensors optimizing the management of energy and maintenance, which are very representative costs of the mining industry. Cybersecurity is also growing in importance for the maintenance of active processes.
- **Energy sector:** This sector is another of the major avenues for the application of smart technology, and it is crucial in all four countries. Energy has two key points of technological development: the transmission and distribution of renewable energy and the potential for improvement to the efficient consumption of energy. Regarding distribution and sale, the challenge is to use sensorization to create a smart grid; meters and smart software will reduce grid losses and optimal demand management will drive consumption efficiency. All connected, integrated and monitored using big data, cloud, IoT and drones. The digitalization of consumer services plays a major role, as this will servitize the kWh produced and create an opportunity for the online matching of the generation process with demand.
- **Waste management:** In this sector, there is full integration of technology into all its processes, from collection, transport and logistics through to final processing in treatment plants. Smart containers, big data, IoT and artificial intelligence (AI) for data transmission and management, in-plant robotics in waste processing and maintenance, and the possibility of using drones for monitoring landfill sites. The goal is to create materials production plants with flexible processes in line with the composition of the materials treated and that are safe for process and maintenance workers and comprehensive in terms of their capacity to recover all materials.
- **Manufacturing sector:** This sector is the main lever of development of Industry 4.0, and so all efforts to promote and consolidate it will be directly reflected in the extension of Industry 4.0 in the countries' national economic development. Manufacturing is a major part of the four economies and there is scope for application of all the technologies and

circular business models proposed. The decision on whether to apply any particular technology will be informed by the circular business mix contained in each company's strategy and each company's ability to incorporate the implicit structural and operational changes.

4.3 Social benefits

Combining circular models and smart technology will lead to an increase in the economic value created by the countries. This increase in economic value will be supported by development of the following particular pillars that are needed to implement the new circular and technological paradigm:

- **Increased technological training**, required for professionals
- The **quality of the universities** and their involvement in the development of guidelines for working in collaboration with companies
- National and international **cooperation** needed to design financially-viable innovation projects
- The **gender-equal** participation of professionals
- Alignment with international **climate-change** commitments and with the other **Sustainable Development Goals**
- The effective implementation of a **culture of innovation and transparency** in respect of the strategies for stakeholders

Integrated in a coordinated manner, all these elements support improvements to people's quality of life. And to do this, they must be taken holistically and used to effectively pull the other economic sectors forward, drawing on a high degree of capillarity of the socioeconomic fabric of the country – and achieving this depends on three key factors:

- The **degree of leadership**, on the part of the government, which needs to be able to create an environment for public-private partnership
- The **quality of institutions**, based on high legal certainty and low complexity of the conditions required for the creation of new businesses
- The existence of a **roadmap agreed with key stakeholders** that sets out the staging and prioritization of initiatives in line with the country's competitive position.

On the basis of the logic used in documents 5.1 and 5.2, it is considered that it is perfectly possible to offset the risk run from other media positions of job losses as a result of an indicator based on "potential automatable jobs" through the definition of a comprehensive, gradual and flexible strategy agreed with all stakeholders. This will produce innovative projects of a different nature that will create a context of effective and efficient transformation for the creation of high-quality employment.

In short, what is being proposed with the development of these combined initiatives based on circular economy models and smart technology is an **ethical**

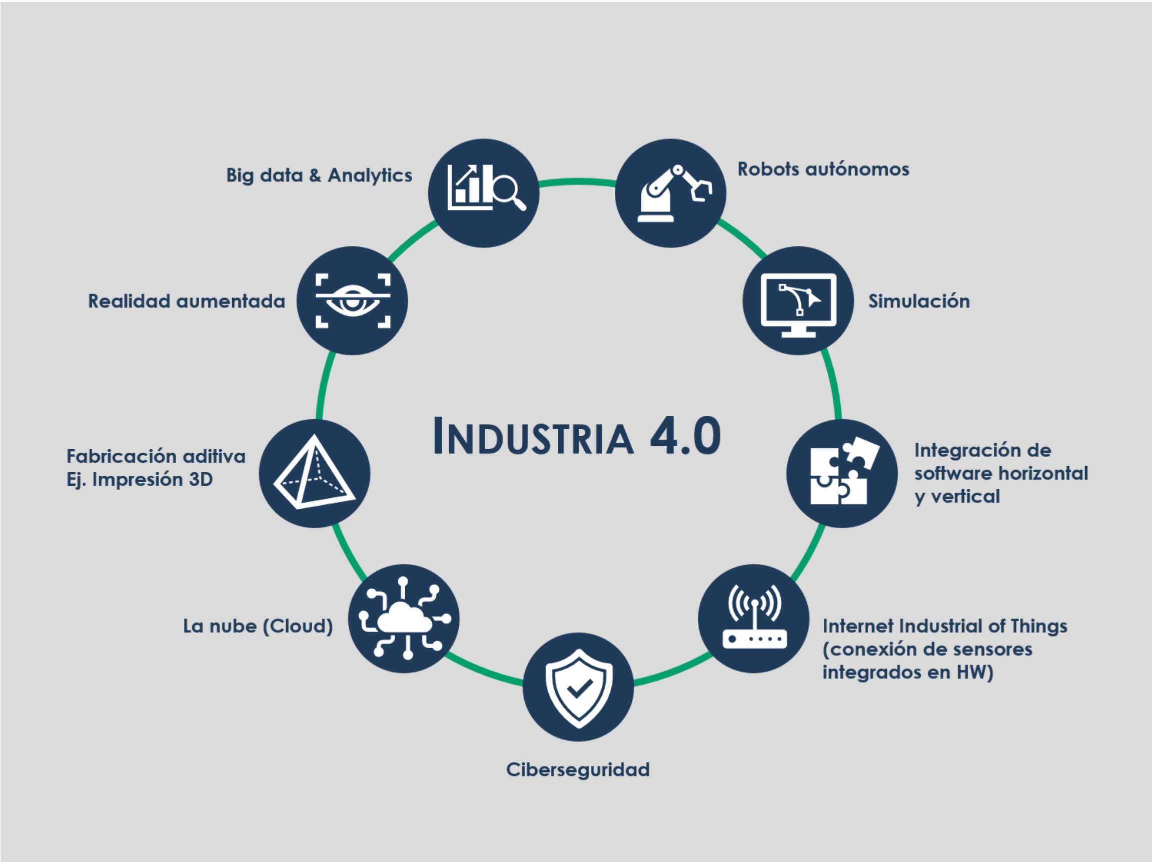
revolution that will underpin the competitiveness of the country and business. Ethical support for the technology will be given by the circular economy, whose philosophy is based on the principles of sustainability.

Annex 1 – The technologies of Industry 4.0

The technologies of Industry 4.0 are oriented towards implementation of advanced manufacturing, integrating value chains and connecting consumers with the production process and business model. Against this background, a series of technologies have been developed whose implementation will depend on each company's competitive market position and the characteristics of the sector concerned. While it is correct to say that manufacturing is the main driver of Industry 4.0 technologies, this is no reason for not giving them proper consideration in the other productive sectors, since their future competitiveness will also depend on the implementation of smart technology.

The following graphic shows the technologies of Industry 4.0:

Figure 1. Technologies of Industry 4.0
Source: Kaizen mejora continua *(Can, s.f.)*



The technologies of Industry 4.0 are the following (list prepared from (ONUDI, 2019)).

- **Big data analytics and Blockchain:** This involves the management and analysis of a volume of complex data that is large and quickly growing, so much so that it is impossible to process using conventional tools within a useful timescale.

  Every user action, such as a keystroke, a query sent to a search engine or a card transaction is recorded, creating a trail of valuable information. This information is crucial, because it reflects users' preferences, current tastes and future trends that can even be predicted using prediction patterns. This example presents the potential for the use of big data.

  This technology has put smart data handling at the service of organizations for them to offer better products to their customers. **However, this technology continues to offer challenges, primarily around data security and unresolved issues such as data ownership, the use of user information and users' authorization for such use.** This is why the use of this technology in conjunction with Blockchain (distributed database secured by cryptography) is proposed, since when used in combination, the information system has improved security, accurate data collection and classification, and transparency.
  Thus, within Industry 4.0, the correct management and analysis of this data necessarily plays a key role, not forgetting that it is the professionals who are ultimately responsible for adding value through the integration and projection of the data to enable the company to take a quantum leap.

- **Collaborative/advanced robotics:** Automation is vital for factories, since it enables processes to be optimized, saving energy, costs and time. Collaborative robots (cobots) were created to help people performing automation tasks and to boost productivity. Cobots are designed to ensure the safety of workers entering into direct contact with the robot in the course of their duties.

- **Internet of Things:** an evolution of the Internet. This evolution represents a radical change to the quality of life for people and to the way in which they interrelate, since it provides a large number of new opportunities, allowing devices to be connected to interact with one another or with centralized devices.

- **Cloud computing:** Platforms that allow collaborative access and the retrieval of large amounts of data from any location and using any device, allowing for very large data flows. These platforms not only allow data storage, but also make it possible to use software over the network without a requirement to have physical infrastructure.

- **Additive manufacturing (3D printing):** 3D printing can produce three-dimensional objects from virtual models, enabling the creation of prototypes, the manufacture of personalized products and decentralized production. Thus, 3D printers are used to make complex parts in less time and at a competitive cost, due to logistics costs being reduced.

- **Cybersecurity:** the protection of digital information. Due to the great evolution brought about by new technologies, protection of information systems and of communication is gaining in importance, especially at a time of interconnections between devices and systems. Thus, cybersecurity ensures companies' protection, privacy and security, securing all the information available about them.

- **Augmented Reality:** Augmented reality uses the physical environment to provide data and information in real time. This technology is a tool that can be used to support production processes and improve decision making using the information that it provides.

- **Horizontal and vertical systems integration:** Systems are able to integrate operational technologies with information and communications technology. They connect machines with other machines and machines with products, and they integrate the different areas of the production unit, impacting the internal management of the company. But they also leverage digital platforms to enable connections between the company and other stakeholders in its value chain, such as suppliers and logistics and transportation operators, through to the customer.

- **Artificial intelligence and machine learning:** with the aim of developing technologies for machines to learn and take decisions themselves. This learning is made possible through the detection of patterns within a dataset in such a way that it is the software itself that predicts what situations may or may not occur. It is these calculations that enable them to learn, to ultimately generate reliable decisions and results. **So-called artificial intelligence and sensors**, combined with cloud computing, offer a growing range of solutions that enable a quantum leap in flexibility, one of the key factors in Industry 4.0.

- **Sensors:** What sensors provide to the system is the connectivity of the hardware components. They comprise a gamut of electric and sensory actuators on the physical components. This is complemented by companies' use of the Internet for data transmission, thus opening the door to the revolutionary concept of "decentralized production".

References

Accenture. (2014). *Circular Advantage: Innovative Business Models and Technologies to Create Value in a World Without Limits to Growth.* Retrieved from https://www.accenture.com/t20150523T053139__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy_6/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf

Automotive Supply News. (n.d.). *Automotive Supply News.* Retrieved from https://www.automotivesupplynews.com.mx/2018/11/21/industria-4-0-futuro-en-el-sector-automotriz-e-industrial/

BENLESA. (2003, 09 23). *Monterrey III: Proyecto de ampliación.* Retrieved from http://www.cca.org.mx/ps/funcionarios/muniapp/descargas/Documentos_de_apoyo/otros/Benlesa-Simeprode_Proyecto_Mty_III.pdf

Cámara Nacional de las Industrias de la Celulosa y del Papel. (2020). *Cámara Nacional de las Industrias de la Celulosa y del Papel*. Retrieved from http://camaradelpapel.mx/

Can, M. G. (s.f.). *Kaizen, Mejora Continua*. Recuperado el 31 de 8 de 2020, de https://manuelguerrerocano.com/cuarta-revolucion-industrial-transformacion-digital-la-industria-4-0/

Cornell University, I. t. (n.d.). *The Global Innovation Index 2019: Creating Healthy Lives—The Future of Medical Innovation, Ithaca, Fontainebleau, and Geneva.*

Díaz Rodríguez, B., Rodríguez, D. B., Montañés Foz, M., Bodas Rodríguez, R., & García García, J. J. (2020). Retos tecnológicos en ganadería de vacuno de carne. *Ganadería. Revista Técnica Ganadera*. Retrieved from http://www.revistaganaderia.com/manejo/vacuno-de-carne/retos-tecnologicos-en-ganaderia-de-vacuno-de-carne_12110_160_15172_0_1_in.html

Ellen MacArthur Foundation. (2015). *Delivering the circular economy – a toolkit for policymakers.* Retrieved from https://www.ellenmacarthurfoundation.org/publications/delivering-the-circular-economy-a-toolkit-for-policymakers

Erbes, A., Gutman, G., Pablo, L., & Robert, V. (2019). *Industria 4.0: oportunidades y desafíos para el desarrollo productivo de la provincia de Santa Fe.* Comisión Económica para América Latina y el Caribe (CEPAL), Santiago de Chile. Retrieved from https://repositorio.cepal.org/bitstream/handle/11362/44954/1/S1901011_es.pdf

FAO. (2009). *El Estado Mundial de la Agricultura y la Alimentación. La Ganadería, a Examen.* Roma. Retrieved from http://www.fao.org/3/i0680s/i0680s00.pdf

FAO. (2017). *El Estado Mundial de la Agricultura y la Alimentación.* Roma. Retrieved from http://www.fao.org/3/a-I7658s.pdf

Ferrovial. (2019, 07 10). *Ferrovial blog*. Retrieved from La Industria 4.0, hacia el futuro del tratamiento de residuos: https://blog.ferrovial.com/es/2019/07/el-futuro-del-tratamiento-de-residuos/

Ford. (2018). Exoesqueleto: tecnología que integramos para reducir la fatiga y lesiones en los trabajadores de Ford de México. Retrieved from https://media.ford.com/content/fordmedia/fna/mx/es/news/2018/08/07/exoesqueleto--tecnologia-que-integramos-para-reducir-la-fatiga-y.html

Ford. (2018). *Ford 4.0: la Nueva Revolución Industrial*. Retrieved from https://www.ford.mx/blog/legado/nueva-revolucion-industrial-201809/

Gerens Escuela de Posgrado. (2017, 10 27). Retrieved 10 14, 2020, from La innovación minera y la tecnología: https://gerens.pe/blog/innovacion-minera-y-la-tecnologia/

Kaza, S., Yao, L. C., Bhada-Tata, P., & Van Woerden, F. (2018). *What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050.* World Bank, Urban Development, Washington, DC. Retrieved from https://openknowledge.worldbank.org/handle/10986/30317

Miclovic, D. (2020, 03 30). En la Minería, Industria 4.0 se Traduce en APM 4.0. Retrieved 10 14, 2010, from En la Minería, Industria 4.0 se Traduce en APM 4.0: https://www.aveva.com/es-ES/Resources/Blog/Industry-mining-translates-to-apm

Ministerio de Agricultura, Ganadería y Pesca. (2020, 10 20). *¿Qué son los inventarios de Gases de Efecto invernadero?* Retrieved from https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/noticias/son-inventarios-gases-efecto-invernadero

Mujer Emprendedora. (2018, 10 11). *enerTIC organiza el Foro de Industria 4.0*. Retrieved 10 14, 2020, from https://www.mujeremprendedora.net/enertic-organiza-foro-de-industria-4-0/

Nissan Motors Corporation. (2012, 03 22). *Nissan Motors Corporation. Sala Oficial de Prensa.* Retrieved from https://mexico.nissannews.com/es-MX/releases/el-ayuntamiento-de-aguascalientes-ener-g-y-nissan-inauguran-la-generaci-n-de-energ-a-el-ctrica-limpia-a-partir-de-biog-s-en-el-relleno-sanitario-san-nicol-s

NTX. (2010, 1 1). *Informador.MX*. Retrieved from NTX: https://www.informador.mx/Mexico/Relleno-sanitario-genera-alumbrado-publico-en-Monterrey-20100101-0116.html

OECD. (2019). *Business Models for the Circular Economy. Opportunities and Challenges for Policy*. Paris: OECD Publishing. doi:https://doi.org/10.1787/g2g9dd62-en

ONUDI. (2019). *Informe sobre el Desarrollo Industrial 2020. La industrialización en la era digital. Resumen*. Viena: Organización de las Naciones Unidas para el Desarrollo Industrial. Retrieved from https://www.unido.org/sites/default/files/files/2019-11/UNIDO_IDR2020-Spanish_overview_0.pdf

paralelo19.mx. (2020, 02 20). Apuesta Volkswagen de México por industria 4.0. *paralelo19.mx*.

Petstar. (2019). *Informe de Sustentabilidad 2019*.

PwC España. (2015). XIV Encuesta Mundial del Sector Eléctrico y de Energía. Retrieved 10 14, 2010, from https://www.youtube.com/watch?v=6eZOevmPHYA&feature=emb_titl

Reportero Industrial. (2019). Cemex lleva la inteligencia operacional a la industria del cemento. *Reportero Industrial*. Retrieved from https://www.reporteroindustrial.com/temas/Cemex-lleva-la-inteligencia-operacional-a-la-industria-del-cemento+131359

Tiempo Minero. (2020). Automatización en sector minero, ¿un enemigo? *Tiempo Minero*. Retrieved from https://camiper.com/tiempominero/automatizacion-minera-es-un-enemigo-al-acecho/

Travel Leisure. (2019, 5 8). *La plataforma Ecolana busca poner fin al problema de la basura en la CDMX*. Retrieved from https://travelandleisure.mx/green-travel/2019/05/08/ecolana-el-mapa-de-la-cdmx-que-muestra-donde-puedes-reciclar-tu-basura/

Universitat de Lleida. (n.d.). *Agricultura de Precisión*. Retrieved 10 14, 2020, from Grupo de Investigación en AgróTICa y Agricultura de Precisión: http://www.grap.udl.cat/es/index.html

World Economic Forum. (2017). *Digital Transformation InitiativeMining and Metals Industry*. Ginebra. Retrieved from http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/dti-mining-and-metals-industry-white-paper.pdf

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