How the digital circular economy works

Circular Bytes Casebook

.AGORIA

sirris
driving industry by technology

imec

GO4CIRCLE

VLAANDEREN
CIRCULAIR

The Circular Bytes team

Authors:
Helen Versluys, Agoria, helen.versluys@agoria.be
Thomas Vandenhaute, thomas.vandenhaute@sirris.be

Project partners:
Agoria — Helen Versluys (helen.versluys@agoria.be) and
Patrick Van den Bossche (patrick.vandenbossche@agoria.be)
Sirris — Thomas Vandenhaute (thomas.vandenhaute@sirris.be)
imec — Kris Van de Voorde (kris.vandevoorde@imec.be)
Go4Circle — Mireille Verboven (mireille.verboven@go4circle.be)

With the support of Circular Flanders

Contributors to Circular Bytes
Helen Versluys (Agoria), Thomas Vandenhaute (Sirris), Ferdinand Casier (Agoria), Isabel Michiels (Agoria),
Patrick Van den Bossche (Agoria), Kris Van de Voorde (imec), Sofie Van Hoecke (imec), Mireille Verboven
(Go4Circle), Nick Boucart (Sirris), Pieter Kesteloot (Sirris), Stijn Gielis (Sirris), Elena Tsiporkova (Sirris),
Anna Hristoskova (Sirris), Tom Klaasen (Sirris), Andy Lambrechts (imec), Annelies Vandamme (imec),
Stijn Smet (Verhaert), Cedric Slegers (Go4Circle), Baudouin Ska (Go4Circle), Caroline Blanch (imec),
Alessandro Murgia (Sirris)

Foreword

Why should circular strategies be supported digitally?

Circular economy is about extending the lifetime of products. By reusing them, by recovering as many high-quality materials as possible from end-of-life products and re-using them in production processes and/or by designing products so that they are upgradable, recoverable and recyclable. Is it possible to move from linear to circular? Yes, provided you know your product through and through. Circular business strategies require more information about a product than sales within a linear model.

For example:
- If you offer maintenance or repair services, then you must know who your end user is and the product's exact location. Before the intervention, you also need to make a diagnosis of the equipment, determine which spare parts are required, and so on.
- In order to recycle the materials from products, you first need to draw up an inventory of all the materials they actually contain: what is valuable and what is not? Are some substances hazardous? But that's not all; you will also need to know how the product works and how end-of-life products are geographically distributed.

Today, such information is often not available. Or if it is, only to one player in the value chain. This is hampering the roll-out of circular business strategies. On the plus side, however, rapid developments in digital technology are helping to overcome this information problem.

This casebook is the product of the Circular Bytes project carried out by Agoria, Sirris, imec and Go4Circle in 2017-2018 with the support of Circular Flanders.
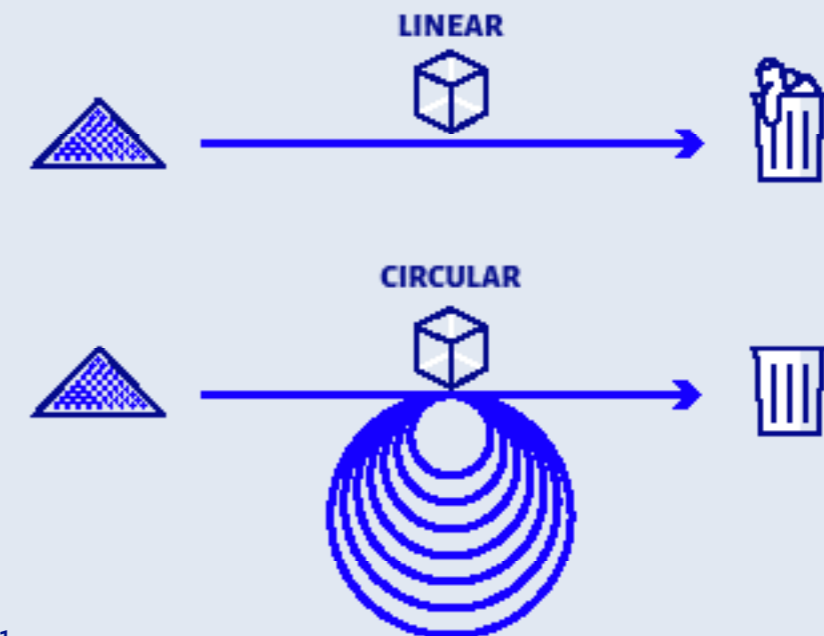

FROM LINEAR TO CIRCULAR ECONOMY

LINEAR

CIRCULAR

Figure 1

Specific questions and the practical experiences of the manufacturing and recycling companies that participated in Circular Bytes were used as a starting point for creating this casebook. The following points are addressed in succession:
- What are successful circular business strategies?
- Which information about products can support these strategies? Where do you find the necessary data? And how smart or connected should products be to collect the necessary data?
- How do you translate the collected, raw data into data-driven decisions that support your circular solution?
- How do you build the circular, digitally supported business strategy step by step?

We also selected 12 inspiring cases characterised by the mutual reinforcement of digital and circular strategies.

This casebook should not be viewed as a scientific study, however. Our ambition is to provide you with inspiration from different angles: circularity, business model innovation and technology. Rather than presenting you with ready-to-use solutions, it invites you to experiment with circular, digitally supported business strategies.

The casebook contains various practical examples. Where the name of a company is followed by an asterisk (*), you will find the case described in more detail in Section 5.

Section 1

Successful strategies for circular economy in the manufacturing and recycling industry

Improved access to financing, greater attractiveness for new employees, the possibility to appeal to new customer groups, readiness for stricter legislation... There is no lack of incentives to implement circular economy. What's more, if you want to make your company future-proof, you cannot ignore it. But how do you create added value, for yourself as well as your customer, while reducing your ecological footprint at the same time?

SUCCESSFUL CIRCULAR BUSINESS STRATEGIES

CIRCULAR

1. SHARING
2. PRODUCT-AS-A-SERVICE
3. MAINTENANCE, UPGRADE AND REPAIRS
4. REUSE & REMANUFACTURING
5. SORTING & RECYCLING
6. REVERSED LOGISTICS
7. CIRCULAR DESIGN

Figure 2
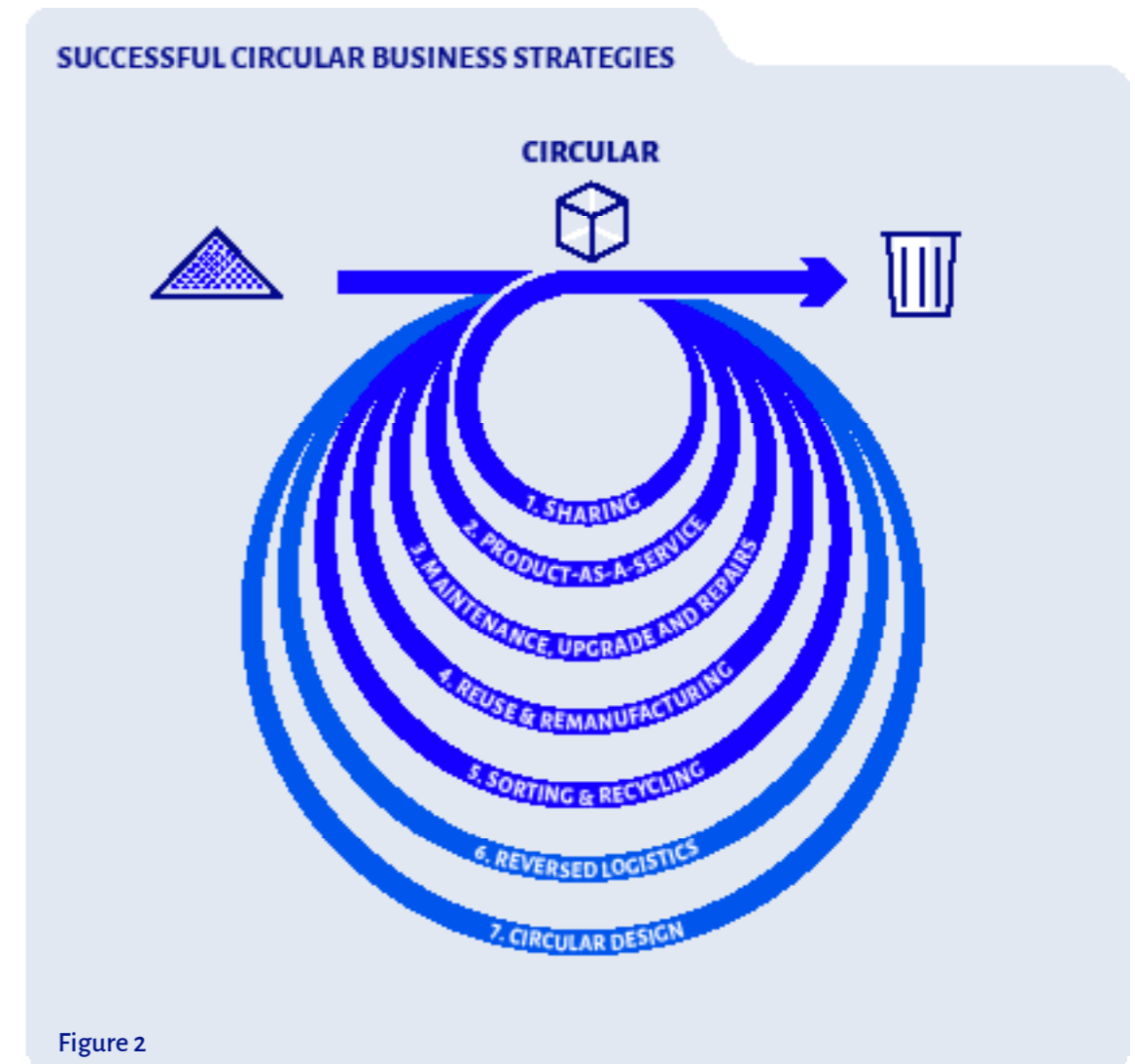
The basic principle of the circular economy is to retain the initial added value of a product as fully and for as long as possible. Not only in terms of materials, but also in terms of added energy, labour and capital. In other words, by processing the product as little as possible before bringing it back into circulation, we retain more of its value and reduce its environmental impact (e.g. CO_2 emissions).

Using concentric circles, figure 2 shows the various – mutually reinforcing – circular strategies that companies are already implementing successfully today

1. Do more with fewer products by sharing or pooling them.

Contraload* offers a full-service pooling service for load carriers, including pallets and boxes. An extensive network of service centres ensures that customers receive quality load carriers and can return their rented material wherever and whenever it suits them best. In this pooling system, Contraload guarantees continuous reuse and repairs whenever necessary.

2. Offer your product as a service: as a manufacturer you remain the owner and you derive maximum benefit from the closed system.

Signify* (formerly Philips Lighting) and **ETAP Lighting** offer Lighting-as-a-Service (LaaS). Under this new business model, the lighting installation remains the manufacturer's property, while customers pay for its use. The advantage for them: without investment they can use sustainable LED lighting based on the latest technology. This allows them to save energy without having to worry about management and maintenance. In addition, the manufacturers take the installation back at the end of the contract. Consequently, this gives manufacturers the incentive to make products that they can reuse. In addition, they can appeal to new segments and stay in close contact with the customer – much more so than with traditional sales – throughout the entire life cycle of their products.

3. Extend the lifetime of your product through maintenance, upgrades and repairs.

SEB's goal: every appliance must be reparable and the means to do so should also be provided. The company integrates repairability criteria when designing its products and measures the degree of repairability of these products. SEB created a stock of 5.7 million spare parts and established an international partner network of 6,500 trained technicians. Offering reparable appliances is a way to boost customer loyalty and discourage purchases from a competing brand[1].
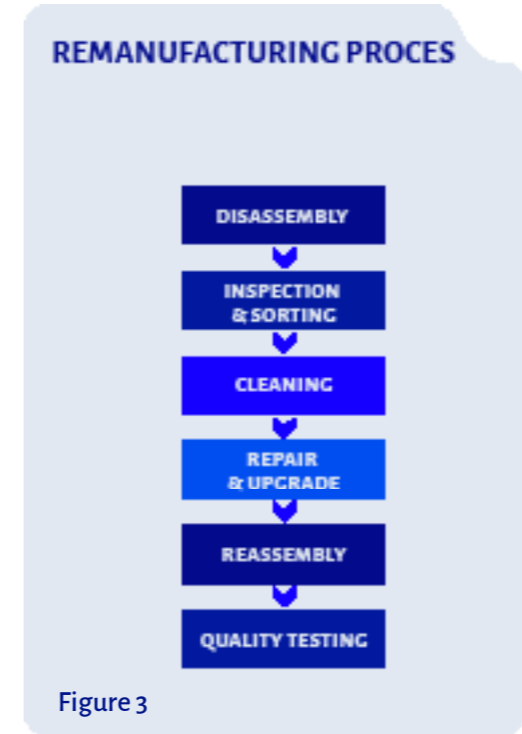

Figure 3

4. Allow your products to last longer with a resale option, whether or not after refurbishment or remanufacturing.

In the case of **refurbishment**, a used product is brought to an acceptable level of quality and aesthetic rework is involved, such as applying a new coating or coat of paint.

Remanufacturing goes further: the used product (component) is brought to the quality level of a new product, meets the latest standards and requirements, and is given a new warranty.

BSH Home Appliances distributes appliances which are resold through the reuse shops. The distributor also does everything to make it easier for those carrying out repairs at the reuse shops: it supplies repair instructions, ensures that the right spare parts are available and provides training. Reuse helps BSH Home Appliances expand its customer portfolio. Suppose a student buys his or her first Bosch or Siemens dishwasher in a reuse shop. Well, chances are he or she will later purchase a new appliance from that brand as well.

At **OriginAir***, a subsidiary of **Atlas Copco***, old air compressors are being remanufactured into new products with the same functionality to give them a second life. Remanufacturing allows Atlas Copco to appeal to a larger customer base, carve itself a slice of the second-hand market for old compressors and protect its brand reputation. Indeed, the high standards regarding quality, delivery times and service for which Atlas Copco is famous also apply to the second-hand market.

[1]More info in French on http://www.seb.fr/produits-reparables

5. Sort products at the end of their life and recycle the usable materials.

Aurubis Belgium[*] melts, refines and recycles copper. Using copper scrap, the company makes copper products with a very high degree of purity.
Comet Traitements extracts metal and plastic fractions from light shredder residue that is generated by shredding end-of-life vehicles or waste electrical and electronic equipment.

To make sure products will flow freely through these concentric circles, the following is also necessary:

6. A logistics system to take back products or collect waste and side streams.

Cisco customers receive a replacement unit within 24 hours. They can return the defective product in the box used for the transport of the replacement equipment. Worldwide, Cisco has 15 major repair sites, which in turn supply 1,300 parts depots.

7. A design that is modular and easy to maintain, upgrade, repair, refurbish/ remanufacture or recycle.

Aiming to design for recycling , **Barco** took a close look at the design of its displays[2]. The dismantling time for printed circuit boards (PCBs), which contain many valuable metals, was drastically reduced by bringing down their number and ensuring that cables are no longer attached to them. The number of screws used was also reduced. The result: substantial cost savings for Barco. This simplified and modular design not only offers advantages when the equipment has reached the end of its life but also during assembly and maintenance.

[2] In the context of the GREENELEC project financed by the European Commission.
Please refer to: https://repository.tudelft.nl/islandora/object/uuid:80628915-8322-4f2f-8196-348bfb92c34d?collection=research.

Section 2

Which knowledge is required to enable circular business strategies to succeed and where do you acquire it?

The combined experience of pioneer companies shows that you should essentially know the following about a product (component): what's in it? How does it work? Where is it? And is it available?

⚬ **Knowledge about the precise composition of a product:**
- Which (valuable and/or hazardous) materials does the product contain, including all additives? And where can every material be found?
- Detailed information on specific parts: processor type, catalyst type, battery type, and so on.

⚬ **Knowledge about the condition and the use of a product:**
- Does it work optimally? Which parts may be defective or in need of service?
- How is/was the product used (e.g. intensively or not, correctly or not)?
- How does the product react to environmental factors (e.g. moisture, temperature)?

⚬ **Knowledge of a product's whereabouts:**
- Who is the end-user of the product?
- Where is the product (component) geographically located?

⚬ **Knowledge of a product's availability:**
- Is it in use or not?
- When is it used?
- What about supply and demand?

TYPICAL CIRCULAR ECONOMY DATA

DATA NEEDS
- LOCATION
- CONDITION & USE
- COMPOSITION
- AVAILABILITY

DATA SOURCES
- CONTEXTUAL DATA
- DATA FROM SMART PRODUCT
- DATA FROM CONNECTED PRODUCT
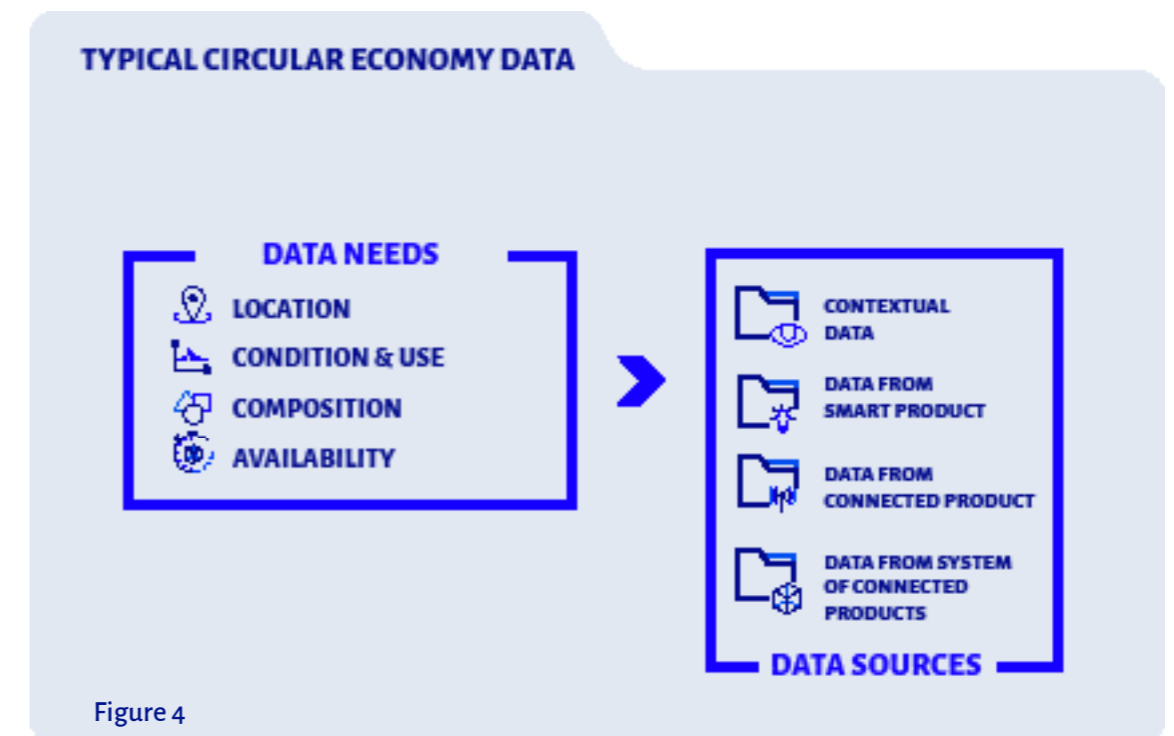- DATA FROM SYSTEM OF CONNECTED PRODUCTS

Figure 4

But how do you gather such data and derive from that insights concerning the composition, condition, use, location and availability of the product in question? Do not fret: you do not necessarily need to have an integrated and connected system to start doing all this. Practice has shown that companies typically use four different data sources – from simple to complex – where the data originates from the product itself or from the value chain:

Contextual data: there is a lot of data on conventional products that you can compile and use to facilitate maintenance, reuse or recycling. For example, think of transactional data (e.g. from accounting, ERP or CRM systems), suppliers' information on product composition (bill of materials), data from maintenance technicians about maintenance and repair services on a product, insights from returned goods (RMA), calendars and data about planned manufacturing shutdowns, online data (e.g. weather forecast), etc. In short, before you make your product smart, you should check which information you already have at hand.

> A digital checklist in the form of an app on a tablet enables selected partners of **Baltimore Aircoil (BAC)** to efficiently collect data on the condition of the product during the periodic inspection of BAC equipment. On that basis, necessary repairs and/or upgrades can be identified, executed and reported. The result: with the BAC inspection app, the technicians optimise their maintenance services, BAC delivers the necessary original spare parts, along with suggestions for upgrades.

Data from a smart product after read-out: you can add sensors to capture additional information about the product – temperature, pressure, load, number of cycles, etc. Data is then stored locally for periodic read-out, for example by the technician during a service intervention. Usually it concerns limited data quantities (e.g. measurement data, rather than long video streams).

Data from a connected product in real time: by connecting a product via the internet, not only is the captured data available on the product itself, it can also be viewed remotely in real time. The communication can be wired or wireless and in one or two directions. And the size of the datasets or streams can be limited or extensive (e.g. video streaming).

> The ready-to-use data loggers[3] manufactured by **ABB** are built into solar inverters. The built-in logging capabilities and direct data transfer to the internet enable customers to monitor the performance of the installation remotely. Customers can use a mobile app to improve their own consumption. It is also possible to compare data from different installations to get new insights about product design, service offering, user instructions and so on.

---

[3] Find out what a data logger is on p37.

Data from a system of connected products: devices also communicate with each other within a network. They perform a self-diagnosis and align themselves with other products; eventually, the product optimisation is done autonomously (by the devices themselves).

> SmartCare by **Barco** is a digitally supported product-service combination that guarantees users of laser projectors complete peace of mind for a period of up to 10 years. It combines:
> - a Barco Smart Laser projector;
> - guaranteed performance level and projection quality;
> - 24/7 technical support and access to an e-support portal;
> - spare parts availability and preventive replacement;
> - remote monitoring to optimise the performance of the projector and extend the life of the light source to 10 years;
> - automatic firmware upgrades.
>
> The connectivity – data from 225 sensors and 6,000 observations per day – provides valuable information about the use and performance of the installed base, for the manufacturer as well as the customer. In addition, both parties can monitor whether programme requirements (e.g. temperature and humidity levels in the projector's room) are respected to prevent breach of contract.

Tip: do not restrict to your own organisation your search for data to implement circular business strategies. In many case, relevant data can be obtained from other players in your value chain: installers, end users, your recycling partner and so on.

> **Internet of Things (IoT)**: physical objects with embedded technology to assess their own internal condition or the external environment and which are connected to the internet to exchange data.
>
> **Big data**: large volumes of unstructured data from various sources that cannot be stored in a traditional database and that require innovative forms of information processing. Big data is used to improve decision making and process automation.

Section 3

How do you translate data into applicable knowledge for a circular business strategy?

There is plenty of data in most companies. Yet not all data is usable or useful. You will find below a possible approach to collecting, accessing and analysing data. You will also find out how you can subsequently use and combine this data with human insights to make informed decisions and roll out your circular business strategy.
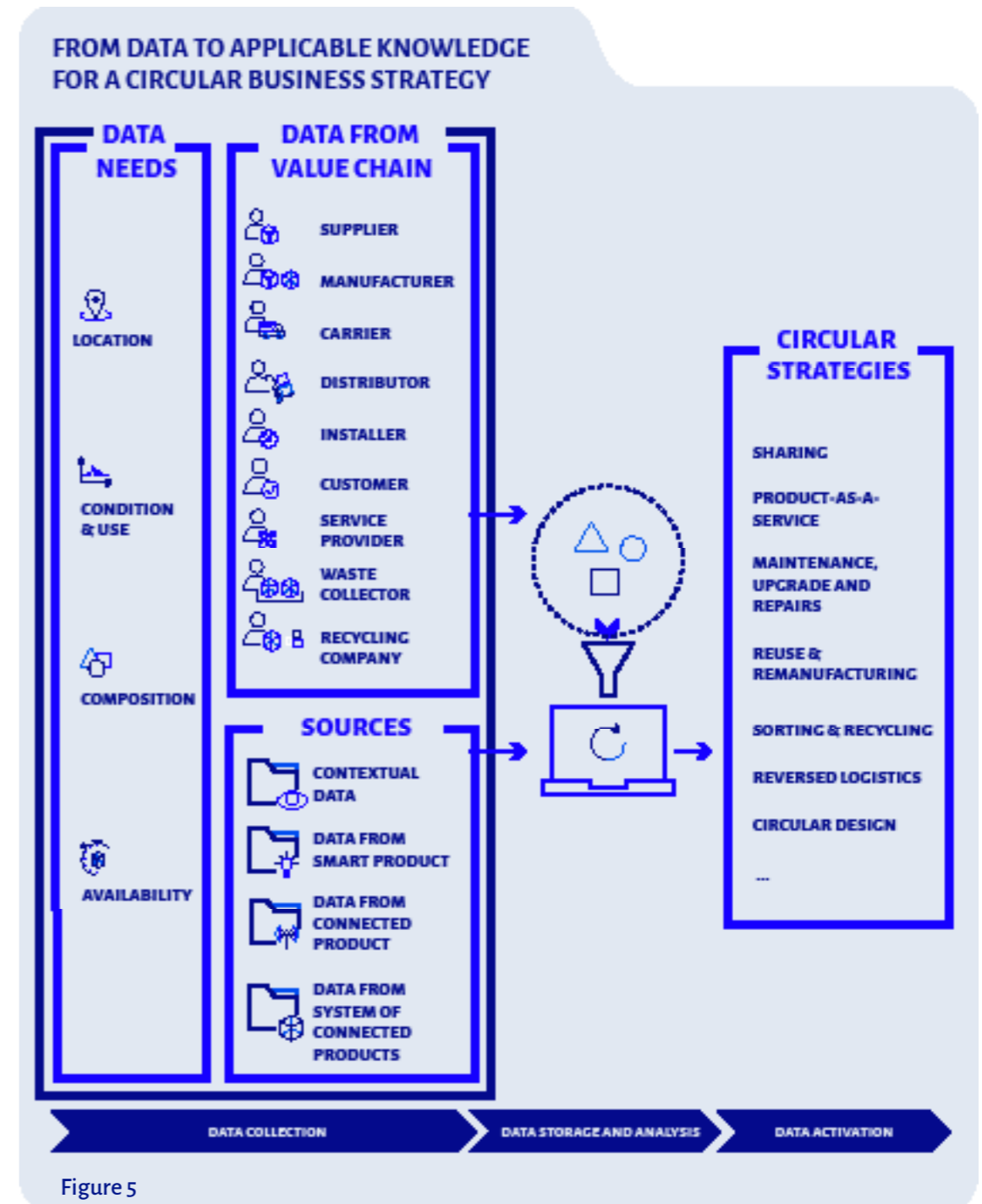

FROM DATA TO APPLICABLE KNOWLEDGE FOR A CIRCULAR BUSINESS STRATEGY

DATA NEEDS
- LOCATION
- CONDITION & USE
- COMPOSITION
- AVAILABILITY

DATA FROM VALUE CHAIN
- SUPPLIER
- MANUFACTURER
- CARRIER
- DISTRIBUTOR
- INSTALLER
- CUSTOMER
- SERVICE PROVIDER
- WASTE COLLECTOR
- RECYCLING COMPANY

SOURCES
- CONTEXTUAL DATA
- DATA FROM SMART PRODUCT
- DATA FROM CONNECTED PRODUCT
- DATA FROM SYSTEM OF CONNECTED PRODUCTS

CIRCULAR STRATEGIES
- SHARING
- PRODUCT-AS-A-SERVICE
- MAINTENANCE, UPGRADE AND REPAIRS
- REUSE & REMANUFACTURING
- SORTING & RECYCLING
- REVERSED LOGISTICS
- CIRCULAR DESIGN
- ...

DATA COLLECTION → DATA STORAGE AND ANALYSIS → DATA ACTIVATION

Figure 5

1.   What is your strategic need for information?

It makes no sense to simply capture and store data. In all likelihood, you will never have the resources to do something meaningful with it. First of all, you need to define your strategic information needs: what do you want to achieve with a circular business strategy? This should help you come up with the right questions.

Suppose that your ambition is to improve reuse and remanufacturing and make it more cost-efficient. Then, those questions could be:

- Where is my product (component) at the moment?
- How intensive is the use of my product (e.g. number of operating hours, load)? What is the level of wear? Which parts are still in good condition and which ones are not? Which upgrades and repairs have already been carried out during the period of use?
- What type of parts (e.g. processor, motor) does the product contain and do they still meet the current standards?
- How exactly is the product built? Or, how can it be disassembled?
- Does the product contain hazardous substances that are no longer allowed after remanufacturing?
- Who is interested in the second-hand product and how much is it worth in its second life?

2.   What does the data processing cycle look like?

Once you have determined your information needs, you go through the various stages of a data processing cycle. In general, these stages are: collecting, transferring and storing, analysing, visualising and taking action.

COLLECTION OF RAW DATA AND LOCAL STORAGE
- Identification of data sources and collection of necessary data.
- Increasingly, sensor data is also stored locally - in the product itself or on-site - and partially processed (e.g. using edge computing).
- Only the selected data is forwarded to the next step in the process.

DATA TRANSFER AND CENTRAL STORAGE
- Combining data provides additional insights. Data from different locations is therefore collected, stored in a central location and made accessible for further analysis and processing.
- The data may be transferred over physical carriers, wired or wireless, continuously or in batches.

DATA ANALYSIS
- During the data analysis, the selected data is carefully scrutinised and interpreted using algorithms (calculation formulas).
- Insights can be drawn as a result to help to answer the initial questions.

DATA ACTIVATION AND VISUALISATION
- Data only becomes really useful if it is activated and supports the decision-making process.
- Data visualisation is an important tool for the processing of large volumes of data. The aim is to use e.g. graphs and trend lines to provide insight into the data at component, product or installed base level, and then communicate that knowledge. All kinds of media can be used to that effect, such as smartphone, tablet, dashboard in a control room, augmented reality, etc.

Figure 6

Did you know that our brain can process visual information up to 60,000 times faster than textual information? Many organisations find it difficult to translate their data into insights, let alone to take action based on that data. Data visualisation helps to understand the data and identify more quickly the patterns, structures and relationships it contains.

There is a wide range of technological solutions for every step: data collection and local storage, data transfer and central storage, data analysis, data activation and visualisation. Sensor systems, edge computing, 5G, artificial intelligence, machine learning, augmented reality, to name but a few technologies, are developing rapidly. In other words, it is becoming easier to build a technology stack to support a circular business strategy. Worth considering in this respect: invest in technology for unique in-house processes, but trust APIs and/or open source for the rest.

Application Programming Interfaces (APIs): today's digital services are no longer coded from scratch. The so-called technology stack consists of layers of one's own and existing code written by others. They are then combined through APIs. In other words: for many applications you do not have to write the code yourself; it is available in the cloud and can be purchased or used. Such examples include applications for e-commerce and invoicing, visualisation dashboards, etc.

Augmented reality (AR): the projection of additional image information on top of the subject's own perception, using smart glasses for example. Pokemon Go is a well-known example of AR taken from the gaming world.

Sensor systems, edge computing and machine learning (cf. p. 38); **artificial intelligence** (cf. p. 72).
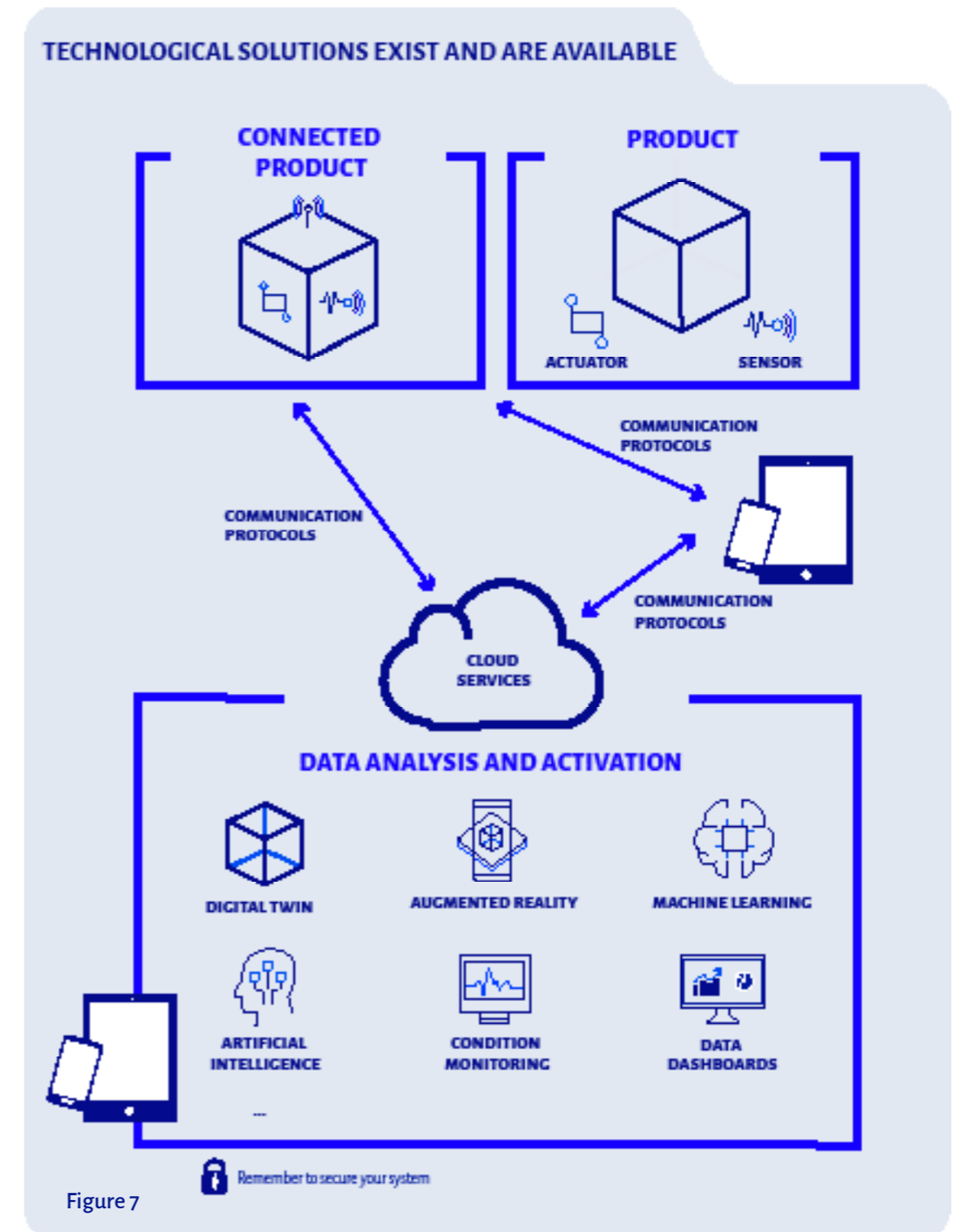

Figure 7

3. How do the insights gained from data help you implement your circular business strategy?

After the data analysis, you have gained more insight into the composition, condition, use, location and availability of your product. But how do you translate that knowledge into a profitable circular business strategy? After a few practical examples of large and small companies, you will find a table detailing ways to harness this knowledge in support of various circular business strategies.

Why should you now invest in the Internet of Things[4]?
- Electronic components (e.g. sensors) are becoming cheaper and more energy-efficient.
- Wireless connectivity is becoming more powerful and more widely available.
- Computing power and storage capacity are virtually infinite and cloud services are easily accessible.

The Reuse Selection Tool by **IBM** can be used to make a well-founded decision about the further use of a complete discarded product or one of its parts: remanufacturing or recycling. This takes into account: product engineering and material data, data on modular construction and reuse potential, usage history, standards, financial data (e.g. market price, remanufacturing costs), supply and demand data, etc.

AW Europe is remanufacturing automatic transmission systems at its Belgian site. Based on data from the physical analysis of the old gearboxes, the company improves the design of the new one.

With Lighting-as-a-Service, **Signify*** commits to match a specific lighting output to a given energy consumption. Monitoring is possible through built-in sensors and connection with the products. With this type of smart products, maintenance can also be optimised. This allows the products to be serviced before any fault can actually occur.

30%
Experience shows that Internet of Things connectivity can reduce the total service and maintenance costs by up to 30%.

Thanks to advanced data modelling, **Aurubis Belgium*** is able to use its customers' production scrap for the production of new copper wire rod at its plant. In addition to monitoring the production process, various sensors also capture data on the quality delivered to the customer. In fact, this provides a good indication of the quality of the returned production waste.

The table below summarises the different practical ways in which knowledge about composition, condition, use, location and availability contributes to product sharing, product-as-a-service, service life extension through maintenance and repair, reuse and remanufacturing, collection, sorting and recycling, return logistics and circular design.

[4]Internet of Things: slimme en internet-verbonden producten en diensten, Dutch Chamber of Commerce, 2014, p. 8.

HOW DIGITAL TECHNOLOGY CAN CREATE CIRCULAR ADDED VALUE

	COMPOSITION	CONDITION & USE	LOCATION	AVAILABILITY
SHARING		- Monitoring the use and condition of a product enables the detection of abuse in the case of shared products and/or contracts. - Condition monitoring can be used to determine whether each user in the sharing or pooling model is getting the promised performance.	- Fast localisation is a prerequisite for sharing products efficiently (locally). Users can easily search for the desired products or services, - The person who knows where the products in a sharing or pooling model are located in real time can plan the (central or decentralised) collection or delivery optimally and organise the logistics more efficiently.	- Real-time information about availability makes shared use possible at an acceptable transaction cost. Users are able to view instantly the availability of the desired products and can book a slot there and then in agreement with the other users.
PRODUCT-AS-A-SERVICE		- Through condition monitoring, a supplier can ensure that the promised service is delivered at the agreed level to each of its customers. - Improved monitoring of the condition and the use of assets in the field reduces the risks associated with the sale of services instead of products. Both supplier and user can monitor whether programme requirements (e.g. temperature and humidity in the room where the device is located) are respected and thus avoid breach of contract. - Thanks to remote management, the costly and labour-intensive service of rented/leased products can be minimised.	- Maintenance and repair services can be organised cost-effectively on the basis of information about the location of the rented/leased products.	- Invoicing can rely on real measured usage.
MAINTENANCE AND REPAIRS	- Inzicht in de locatie van (slijtagegevoelige) componenten in het product laat efficiëntere herstelactiviteiten (bv. demontage, vervanging, montage) toe. - Kennis over de gebruikte materialen verkleint het risico op contaminatie door gevaarlijke stoffen uit gerepareerde producten.	- Companies can offer their customers customised advice on the correct use of the product. Avoiding misuse will reduce the risk of premature wear and prolong lifetime. Energy and water consumption, among other things, can also be minimised. - By (remotely) upgrading the operating software in the use phase and by integrating the latest firmware, old devices/appliances remain competitive for longer and replacement is delayed. - There is no need to wait until the device/appliance e.g. fails to perform to have it serviced or replaced. Intelligent products detect errors themselves and propose solutions. They indicate when maintenance, repair or replacement is required. Preventive and predictive maintenance extends lifetime and service intervals are optimised. - Contextual work instructions can be created for technicians by combining current and historical data on the condition of the product. Using augmented reality or connected apps, they help increase the efficiency of servicing and raise the first time fix ratio	- Knowledge of the location of products or parts in the installed base allows us to plan the service as efficiently as possible. - Insight into the geographical spread of products enables the roll-out of a network of local service hubs, possibly in collaboration with partners. - Supported by current information on the location of new or second-hand parts, the spare parts logistics can be optimised and repairs run smoothly.	- Knowing when a production machine is in use and information on use patterns allow us to better schedule maintenance, upgrades or repairs. The service activity can then be carried out without a negative impact on the machine's production output.
REUSE AND REMANUFACTURING	- Knowledge about the product's structure makes more efficient remanufacturing (e.g. dismantling, inspection, cleaning, repair and upgrading, and new assembly) possible. - Knowledge about the materials used reduces the risk of contamination by dangerous substances from remanufactured products.	- Knowing the condition of a device/appliance allows accurate decisions to be taken concerning future circles: is a product still in a sufficiently good condition for reuse or to recover parts (parts harvesting), whether or not after refurbishment or remanufacturing? Or is recycling a better solution?		- Better insight into supply and demand helps make decisions about reuse: is there still a demand for the product and what is the estimated residual value at the end of its useful life? - Digital marketplaces match supply and demand and thus facilitate the sale of second-hand products and parts.
COLLECTION, SORTING AND RECYCLING	- The recycling threshold is reduced when the information about the exact composition of products and the materials used (including all additives) is available at a reasonable price. Indeed, processors of discarded products can sort specific components or substances (e.g. batteries, screens, cooling gases, oil, insulation, rare earth metals) and recover them more optimally. - Detailed information on specific parts (e.g. type of processor, nature of the catalytic converter, type of battery) may help choose the right recycling avenue and shorten the recycling process. - Identification of hazardous substances and valuable and critical materials increases the insight into the costs and yield of the recycling process.		- Information about the location of products is a prerequisite for efficient collection logistics.	- In waste logistics, digital versions of the (compulsory) transport documents reduce the risk of errors compared to manual input. In addition, they facilitate the flow of information between trading partners[5].
REVERSED LOGISTICS	- Knowledge about the product composition increases the insight into the necessary subsequent processing steps and, as such, into the various possible logistic movements that may be necessary to get products/parts to the right processing.	- Knowledge about the product condition increases the insight into the necessary subsequent processing steps and, as such, into the possible logistic movements that may be necessary to get products/parts to the right processing.	- With product tracking, return conditions and reverse logistics at the end of the (first) commercial life can be further optimised, with a view to possible reuse or recycling. - Information about the location of products that have to return provides insight into the usefulness of setting up local/decentralised hubs for return.	
CIRCULAIR ONTWERP		- Thanks to digital technology, the user can give a personal touch to the product and adapt it to his/her own (changing) needs by adding or removing functions, integrating it with other applications, changing operating parameters, etc. This will ensure he/she will be less inclined to replace the product and will take care of the product. - Large amounts of feedback data on usage, maintenance history and failure modes enable designers to identify design flaws and optimise design.		

Section 4

How successful companies start up their digitally-supported circular business

1. Use the lean start-up method

Imagine that, as a machine builder, you are planning to launch a machine with a maintenance contract on the market. The idea is that your customers will have the opportunity to upgrade the machine. On top of that, they will receive continuous feedback on their energy consumption and usage-related costs, so that they can keep them to a minimum. They will not collect and analyse this data themselves; instead, they will receive practical tips to use the machine more optimally. You want to offer this solution as a service for a monthly fee. How should you proceed?

The lean start-up method is a good way to embrace a circular and digitally-supported business model, also for established companies. The more the new model differs from the existing one, the higher the yield from this method. It generally goes through 4 stages: (1) generating ideas (Idea Generation), (2) finding suitable solutions for the problems identified (Problem Solution Fit), (3) investigating the solutions' economic feasibility (Product Market Fit) and (4) upscaling of products and services (Scaling). Each stage has its specific challenges and the use of technology differs from one step to the next. The reasoning behind the method is as follows: don't manufacture a new product or create new software before you know whether your target group is waiting for it.

1. In the first stage – **Idea Generation** – customers are asked for their feedback on their problems and needs which are then mapped and linked to possible solutions. The focus is on building and strengthening market and customer knowledge. Specifically, this takes the form of F2F, telephone or online surveys (e.g. by email or over social media), sometimes with the help of a checklist. Conducting the surveys and processing the acquired data requires little technology.

Metal processor Diericks Tools works with machine tools. As such, it has come to learn the importance of high-quality cooling emulsions. Because of this need stemming from its own experience, the company had the idea to build a device to ensure the condition monitoring of cooling emulsions. **WillFill** * was born.

Tip: Filling in the Value Proposition Design Canvas helps you answer the question as to whether your proposed solution actually resolves a problem at an (internal/external) customer.

2. With the **Problem Solution Fit**, it comes down to describing a product, service or a combination of both that serves the needs of the customer and for which he/she wants to pay. You simulate a **minimal viable product** (MVP): the most minimal, fastest-to-create, workable product that allows you to answer the question as to your customer's exact needs. Think of storytelling, mock-ups, prototypes, simulations using open source tools and so on. Assess the financial viability as well: find out how much your customer – in order of magnitude, of course – is willing to pay for the solution. The difference between 10 euros and 100 euros per month has a huge impact on the product you can build and/or the services you can link to it. For example, publish a YouTube video or create a mini-site where the (not yet existing) product is briefly described and interested parties can register. By varying the description or price setting, you already obtain some information about the needs of the potential users and their willingness to pay. At this stage, you also have room to 'pivot', i.e. adjust your plan.

3. During the **Product Market Fit** stage, you check the economic feasibility for a larger group of customers and different customer segments. The MVP is sold and tested within a broader target group. They should not just like your product, but indicate that they would be really dissatisfied if they could no longer use it. Your own company targets are also clear at this stage: how many euros do you need to allocate to each product and customer to ensure you have a profitable product?

> **TVH*** needed a dashboard to visualise the information about their leased connected products. An MVP was developed in close cooperation with the customers, while focusing on managing machines on large building sites. Soon the added value of such a dashboard became clear to a broader target group. Since then, event organisers are also using the dashboard and the associated planning tools.

4. The products and services are scaled up during the **Scaling** stage. The goal isn't to further expand the functionalities, but to attract more customers. The emphasis is also on optimising the business processes: service personalisation, communication, reduction of the costs to acquire and service a customer, etc.
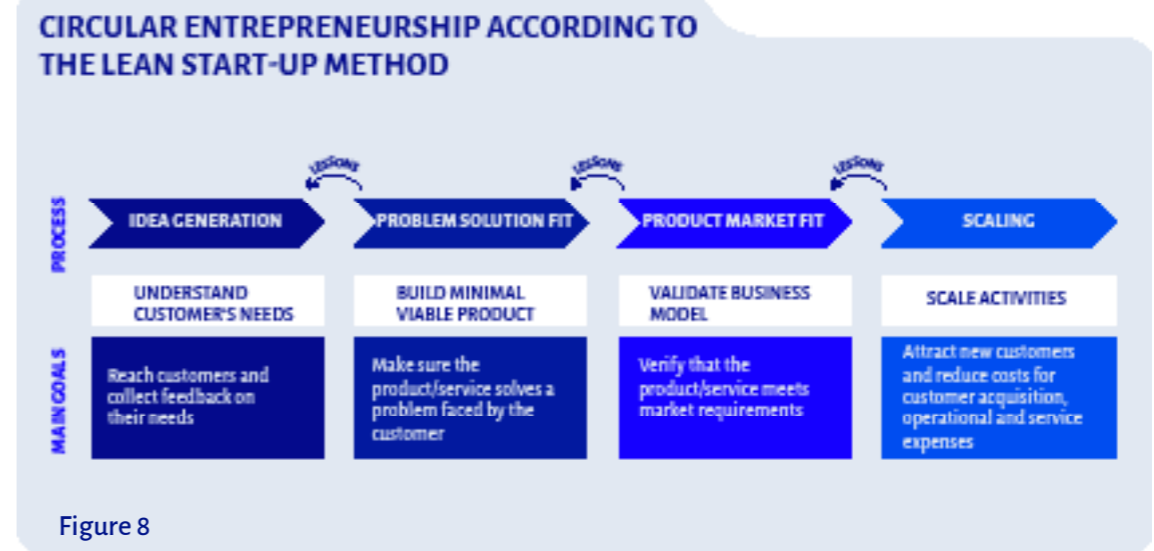

Figure 8

2. Tips from industry peers to increase your chances of success

1 Don't collect data for the sake of having data: start simple

The lack of a clearly defined information requirement is often the reason why a data project does not meet expectations. Setting up digital systems is therefore not an end in itself, but a means to achieve a tangible business goal. First determine which information you need to help your business move forward and make it more circular.

Then build your data innovation project step by step. Small-scale experiments will allow you to gain experience without overspending. Apply the fail fast method at this stage.

> **Tip: See if you can initially use Excel spreadsheets to collect and manage data. Later, you can invest in extensive software for data analytics or cloud infrastructure. This allows you to learn by doing how to link data and determine which information is redundant.**

It comes down to gradually increasing the complexity. Start by capturing a limited set of raw data in function of the identified information needs and gradually expand your scope. Having all kinds of peripheral data will not necessarily facilitate the decision process after all. Another important tip: start with the data you currently need. You will still be able, at a later stage, to think of new ways to create added value and consequently develop additional services.
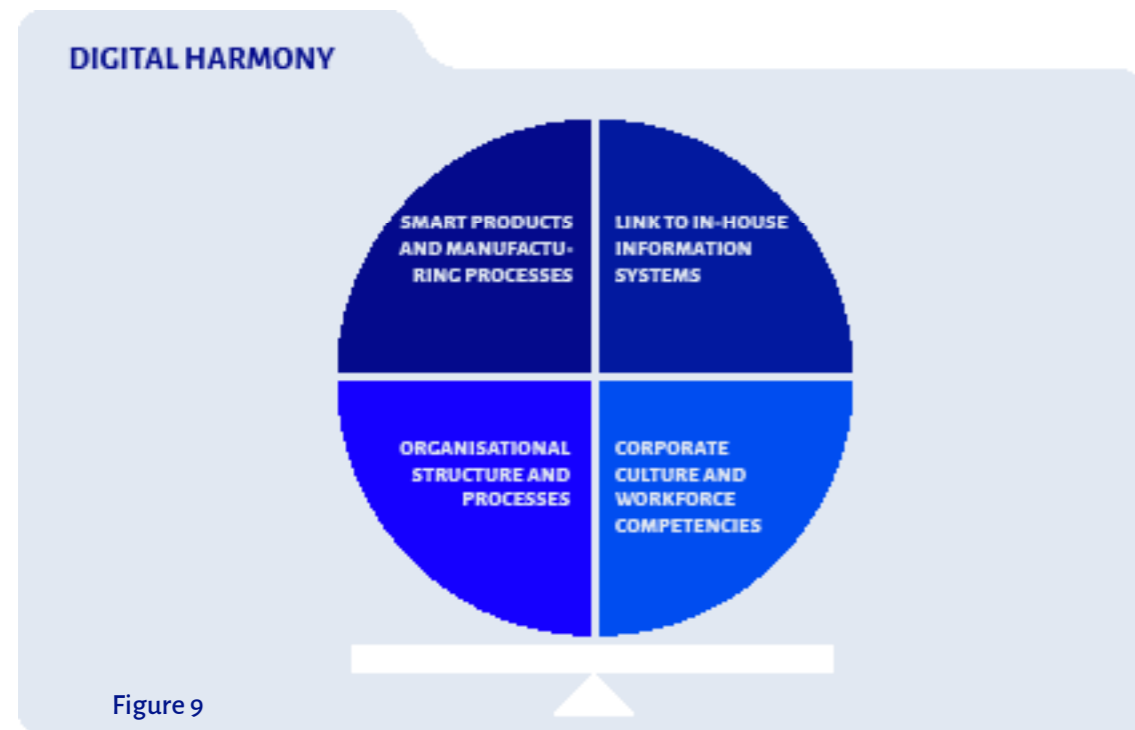
2 Technology won't solve all your problems: maintain a balance

Data innovation is not just about technology: in fact, it is situated within each of these quadrants:

1. make products or production systems smarter to collect additional data;
2. link with the company's information systems (e.g. ERP, CRM);
3. corporate culture and the competencies of the workforce;
4. adapted organisational structure and processes.

Keeping this balance is a recipe for faster success.

Bests practices in digital transformation suggest that investments in process improvements, training and reorganisation, must exceed the investment in ICT by a ratio of 4 or 5 to 1.

DIGITAL HARMONY

SMART PRODUCTS AND MANUFACTURING PROCESSES

LINK TO IN-HOUSE INFORMATION SYSTEMS

ORGANISATIONAL STRUCTURE AND PROCESSES

CORPORATE CULTURE AND WORKFORCE COMPETENCIES

Figure 9

3 Involve everyone in the circular and digital strategy: create buy-in and invest in the right skills

When the process towards a digitally-supported, circular business strategy is not supported by all employees, its chances of success are low. Internal marketing to increase support for circular entrepreneurship is therefore a must. Many departments – production, R&D, sales, legal, etc. – should definitely be involved.

Similarly, digitisation is not the monopoly of the ICT department. In short, reflect on ways to make the new corporate vision the vision of all employees. This way you can demonstrate how circular and digital entrepreneurship will help everyone achieve their own objectives. Above all, you need to create buy-in within your management team.

The support you get from your workforce can also play a part in the choice of one technological solution over another, certainly in the initial phase. For example, complex applications require the necessary knowledge and experience, while simple tools (like Excel) can be used immediately and with limited instructions. In any case, training, including on-the-job, is a must.

4 Work together: look for the win-win for all partners

For circular entrepreneurship to happen, the entire system needs to be optimised, something you can never do alone. Collaboration is therefore necessary: within the organisation, between organisations and with customers. For instance, partnerships between designers, waste processors and manufacturers to make products that are easier to recycle at the end of their life cycle. Or a manufacturer which, together with its suppliers, adapts the materials used; or which, in collaboration with a customer, devises upgradable, multifunctional products. Or a manufacturer partnering with a maintenance company to set up a remanufacturing and reuse programme. Or, finally, companies that make use of each other's waste flows in their own production process.

Since manufacturing and recycling companies operate in a very competitive environment, setting up partnerships is not an easy task. Here are ways to build trust:

- First and foremost, try to find common objectives. Examine your circular business strategy from the point of view of your suppliers, customers, distributors, installers, logistic service providers, investors, and so forth. Where is the win-win for all partners involved?
- On a project basis, come to a clear-cut agreement on the assignment of tasks and of the responsibility for the timely delivery of specific results.
- Once the initial collaboration has run smoothly, you can give those agreements and working methods a more formal, contractual form. For example, it is possible to draw up SLAs (service level agreements) and contracts that include procedures for when something goes wrong, IP agreements and so on.

5 Use and share information thoughtfully: gain timely legal advice and build secure systems

Suppose you manufacture production machines equipped with sensors. With these sensors, you measure and collect all sorts of data, such as number of operating hours and the frequency or nature of faults. The measurement data is then sent to a server at an ICT specialist that you had tasked with developing an algorithm to analyse the data. With the help of an app, you are now in a position to advise the customer on the need to service the equipment and/or replace wear parts. Since the measurement data has a commercial value, you absolutely don't want it to fall into your competitors' hands. But who is actually the owner of the unprocessed sensor data? And of the data generated by the algorithm? There are no explicit rules about the rights to digital data in the form of technical information about a machine. As a result, partners must agree to contractual provisions stipulating:

- Which type of data can be collected and for what purpose?
- Who owns the big data?
- Who bears the legal responsibility if something goes wrong?
- …

A lot of the data in B2B markets is not privacy-sensitive. But if you also work with personal data, you should take the necessary precautions. The famous GDPR – which stands for General Data Protection Regulation – implemented by the EU is now in force after all. If your company is active internationally, you should also check whether it must adhere to specific rules for cross-border data transfers. And if you want to collect and remanufacture used products or parts, check whether strict waste management and transport rules apply.

When you share information with your partners within the value chain data on the composition, condition, location and availability of products, proceed with caution. By connecting devices to the Internet, you create new links that hackers may breach to gain access to company-sensitive information. In other words, increasing connectivity also raises the importance of security. Build safe systems based on existing technology and save costs by using open protocols.

Section 5

12 inspiring cases in which digital and circular strategies reinforce each other

In the final part of this casebook, we present you with 12 inspiring practical cases from manufacturing or recycling companies that successfully use digital technologies to do business in a circular way:

1. Atlas Copco/OriginAir: smart air compressors enable remanufacturing and Machine-as-a-Service

From product to Product-as-a-Service combinations

Ten years ago, it became clear to Atlas Copco that the company should focus on the servicing of its compressors. The contribution of maintenance services to turnover and profit had proven to be more stable than that of volatile machine sales.

Atlas Copco offers so-called total responsibility contracts in mature markets. Under those contracts, the company is fully responsible for keeping its compressors running on site. It also provides customers with advice on optimal use of the machines to ensure they consume less energy and last longer.

Several pilot projects on Machine-as-a-Service (MaaS) are currently running. The customers pay for the operating hours, which means they no longer have to buy the machine. The plan is to build up experience and to gauge through trial and error whether the design needs to be modified in order to further optimise moving and servicing the equipment. As a next step, Atlas Copco is aiming to set up Compressed-air-as-a-Service (CaaS), the ultimate servicing model in which the customer pays per cubic metre of air. All costs are to be borne by Atlas Copco, including energy which accounts for about 70% of the total cost of ownership of a compressor.

Remanufacturing

Since 2012, Atlas Copco's subsidiary OriginAir specialises in the purchase of air compressors at the end of their first life. The remanufacturing company processes the used equipment until it is qualitatively equivalent to a new one.

Remanufacturing allows Atlas Copco to increase its market share and appeal to a broader customer base. On the one hand, there are companies which, despite a limited budget, would like to be able to avail of the high quality procured by a top brand. On the other hand, there are entrepreneurs who consciously choose to combine new and remanufactured machines. To reduce costs, for example, or because this combination fits their needs better. The remanufactured machines may act as a back-up in their compressed air chamber. Companies urgently looking for a machine will get a faster delivery if they opt for a remanufactured compressor. The lead time for remanufacturing usually doesn't exceed 4 to 5 weeks.

"If a remanufactured machine is sold again, its lifetime has been extended. In other words: one machine now has two lives."

— Ahmed El Ghalbzouri, Business Development Engineer at OriginAir

OriginAir does not mass produce: every machine is inspected and overhauled as an individual project, in accordance with the specifications supplied. Specifically, each machine can be adjusted in such a way that it meets the new owner's requirements optimally. During the process, the machine also has the SmartLink IT solution built into it.

Circular and connected

Atlas Copco has been making its compressors intelligent ever since 2013 by fitting them with the SmartLink IT application. Sensors provide insight into the exact usage of the machine, thus enabling fine tuning to limit wear and reduce power consumption.

Sensors: detect physical conditions such as location, movement, pressure, temperature, humidity, speed, colour or chemical composition.

Data loggers/edge computing: data loggers are small, portable devices that are equipped with one or more sensors and a microprocessor, an internal memory for data storage. They may be either powered by a battery or connected to the mains supply. Some data loggers communicate – via a wired or wireless connection – with a computer to read out data. Other loggers even have their own keypad and LCD screen.

Actuators: while a sensor records its perception of the surroundings and transmits this data (e.g. temperature measurements), an actuator performs an action based on the impulses obtained (e.g. switching the heating on or off via a relay). An actuator may take the form of a motor (rotating, linear), an electromagnet, a relay, an electric or pneumatic switch, and so on.

It is now possible to read out the sensors remotely, in addition to directly on the machine itself. Currently, 141,000 machines are connected; some 90% of Atlas Copco machines are fitted with SmartLink. Maintenance is timed more accurately and is more efficient as a result. What's more, the collected data allows the company to improve the design of new products.

"While our engineers used to make all kinds of assumptions as to how exactly customers were using our products, now they can also test them."

— Wouter Ceulemans, President Airtec Division at Atlas Copco Airpower

Via SmartLink the OriginAir team also knows whether a machine is still operational or not. If this does not appear to be the case, the machine becomes a potential 'buy back' and the company will contact the owner to make an offer. SmartLink also provides insight into, among other things, the number of operating hours and service calls, all in all useful information to estimate a correct residual value.

Atlas Copco purchased SmartLink as a standard tool and also uses standard software packages for machine learning.

Machine learning: computers are able to learn independently of input and events, in other words without additional programming or software for every new event.

Towards condition-based monitoring
In a next step, artificial intelligence will recognise patterns in the behaviour of a compressor and, based on this data, determine precisely which type of servicing is needed and when. Letting machines learn means feeding them with vast amounts of well-labelled data. In this particular case, this means data from a large number of compressors in many different operational situations at many plants and over a long period. However, the 3G and (soon) 4G connections that Atlas Copco uses to communicate with the installed base have limited capacity. The challenge is therefore to acquire maximum insights with a minimum of sensors and data.

When it comes to big data, the next step is directly linked to subsequent developments in the servitisation strategy:

"In order to be able to apply the MaaS model properly, we need to have completely mastered condition-based monitoring. After all, the equipment will remain on our balance sheet and at the end of the term of the contract we will take it back."

— Wouter Ceulemans, President Airtec Division at Atlas Copco Airpower

One of the challenges – and a condition for the CaaS contract form – is to make sure energy consumption can be measured reliably from a distance.

New business models require different knowledge and skills

The new business models also mean changes for the staff, as employees need to acquire new knowledge and skills. Designers, for example, need to master design for serviceability, by designing products in a way that they will consume a minimum of energy and require very little maintenance. In addition, the wear parts must be easily accessible to the fitter. Considering that technology and data are set to play an increasingly prominent role within Atlas Copco, the company is actively looking for electro-mechanical and software engineers, as well as data analysts and data scientists. Basic data literacy is also a plus in each function.
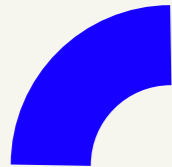
"Today's compressor is no longer a mechanical machine but a high-tech device. This has also changed our needs in terms of recruitment. We are constantly looking for people with the right competencies, and especially the right 'attitude'. We don't restrict our recruitment criteria to diplomas or experience: anyone who is bitten by the sudoku bug or a crack at Excel may apply for a job with us."

— Wouter Ceulemans, President Airtec Division at Atlas Copco Airpower

2. Aurubis Belgium: data modelling ensures optimal recycling of customers' production waste

What about high-quality copper scrap resulting from production processes at customers?

At its Olen plant, Aurubis Belgium produces copper wire rod that its customers later process into copper wire and cable. The rod is tailored to the customer's specifications in order to supply optimum quality for the final application. Different aspects are important to the customer, including conductivity, surface quality and yield strength. The quality of the raw material and its metallurgical processing are key influencing factors; as are the possible inclusions from the melting and/or rolling operation. Intensive quality monitoring is already performed during the production process via online measurements with various sensors.

The production scrap at the customers of Aurubis Belgium consists of high-quality copper, that may or may not be sheathed in insulating material. However, during the first processing at the customer, contamination often occurs which prevents the immediate reuse of this production scrap in the production of wire rods. This could have a negative impact on quality. Refining the pure scrap fully is an alternative, but this is not ideal, both environmentally and economically speaking.

That is why Aurubis Belgium developed a modelling based on the available data so that it would be able to recycle the high-grade copper scrap directly into the melting furnace to make wire rod without compromising on quality in any way.

Data modelling in real time

The following, and already available, data was used as the starting point for the modelling:
-    existing working orders from customers with the required quality and delivery times;
-    information about the quality supplied to the customer, a good indication of the quality of the returned production scrap;
-    the quality that is currently being produced for the customers;
-    various sensor measurements in the production process.

The outcome of this real-time modelling was integrated in the process control to allow the operator to recycle optimally the customer's production scrap into the melting furnace and still produce the required quality. The modelling is based on the quality requirements for wire rod that is produced for a particular customer at that time and takes into account the available quality of the contaminated copper scrap.

However, the logistics involved in receiving the sometimes small quantities of production scrap back from the customer remains a considerable hurdle. A more thorough separation of the various scraps throughout the production process would further facilitate recycling. But since it concerns limited volumes in any case, excessive sorting would exacerbate the logistical challenge even more so. That is why this modelling, which starts from all available data and has a built-in learning effect, offers added value for Aurubis Belgium and its customers.

"With this modelling, we stop production scrap, in itself pure copper, from having to go through the entire refining process in order to achieve the same purpose. The cost savings, with regard to lead time as well as operational costs and energy, are significant. In addition, the generated data is reintroduced into the model during the process so that there is a learning effect. This will enable us to use this high-grade copper scrap even better in the long term."

— Jo Rogiers, Vice President Technology at Aurubis Belgium

The modelling technology was implemented recently. The first results show that the model thus developed delivers good predictions in terms of production quality and is a means to use this high-grade scrap at the end of the process without compromising the final quality.

The next step, i.e. upscaling to freely traded copper wire scrap, is much more difficult, however. In a short B2B chain, the necessary information about initial impurities in the scrap is available, something that is missing on a larger scale. The batches offered by the scrap sector are often too heterogeneous and an exact characterisation of the impurities is not readily available.
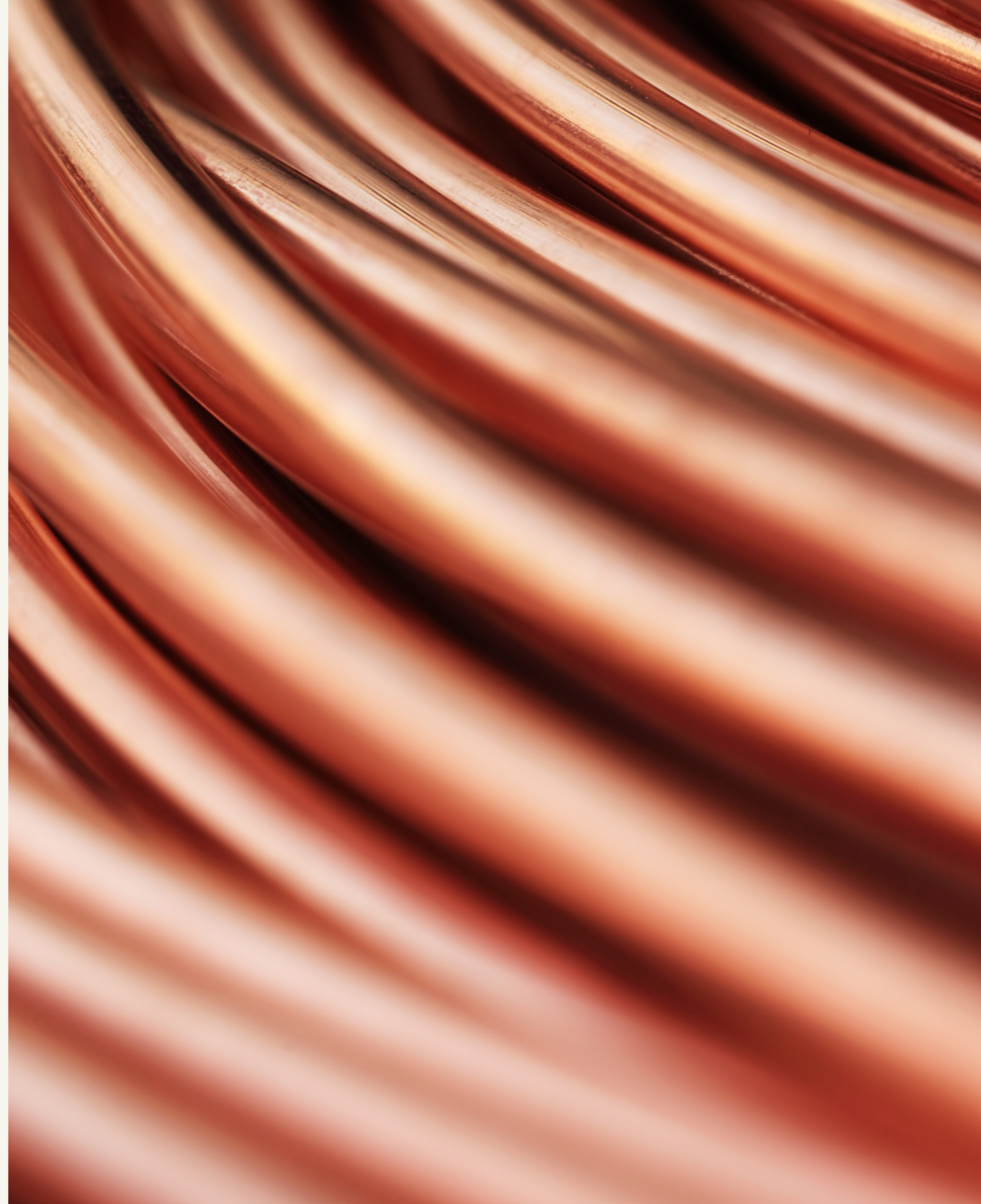
3. Circularise: eliminating communication barriers between manufacturer, user and recycling partner

"As a company, you can try to implement a circular strategy on your own. But if you do, you will never achieve efficient circular economy on a large scale. For that to happen, you need to share information throughout the entire value chain."

— Mesbah Sabur, founder of Circularise

Contribution to the circular economy

From the outside, nothing indicates whether, e.g. electrical or electronic equipment contains a battery or mercury lamp, or where the valuable PCB is located. Unscrewing every cover of countless old electronic appliances to inspect their contents in a recycling plant is expensive and sometimes entails unnecessary manual handling. However, the parts manufacturers or the manufacturers of the appliances do know whether certain components are present and where they are located in the product. Yet, this information does not necessarily trickle down to the recycling partner.

Why is the communication about the materials and products not maintained throughout the stages of the value chain, from mining to manufacturing and consumer use, possibly a second life and finally recycling? The founder of Circularise sums it up nicely: "Even though all the stakeholders have part of the info, no one has all the pieces of the puzzle. A supply chain is a complex structure whose actors may not know each other. When planning future innovations in reverse logistics and recycling, it is often not yet clear which data exactly will be needed. Finally, many stakeholders are not keen to share their (sometimes) sensitive information and/or trust a central player, as this could have a negative impact on their competition edge."

In other words: it boils down to finding a solution that allows product information to move safely and efficiently through the value chain while keeping it up-to-date.

This is what Circularise has achieved. This communication platform for the circular economy offers all parties direct access to the relevant product information. For consumers, this includes the warranty, manuals and maintenance and repair instructions. Recycling companies, for their part, receive data about the product composition in order to be able to sort faster and better. Manufacturers, finally, gain insight into the users of their products and get feedback data from the recycling phase to improve the design of their next generation products. They can also use the platform to increase transparency in their own supply chain and gain a better understanding of the origin of the materials and components they use in their products.

The technology

Unique IDs are assigned to materials, parts and products. The labels range from QR codes to RFID (Radio Frequency Identification) or NFC (Near Field Communication). A label can be scanned by the manufacturer, the consumer or the recycling company. Professional users have access to a user-friendly interface to read or write data. End users can use an app which gives them access to all relevant product information and constitutes a point of contact with the manufacturer. An API ensures easy integration with other existing applications.

Circularise does not manage the data itself: even though the company sets up a protocol, the communication is peer-to-peer via blockchain. The system is built in such a way that even the developers of the platform cannot see the secured data.

A **blockchain** acts as a democratic repository for data. Each transaction between parties is established in a secured way (a block) and linked (the chain) with earlier and later transactions of those parties. Consequently, there is no central authority managing everything; the repository is divided among all participants. Imported data cannot be altered without leaving a trace, which excludes fraud. Information can be shared anonymously through encryption.

The participating organisations must have tokens in order to use the Circularise platform. They can use them to pay for using the system and to generate product labels. Tokens can be exchanged for labels by participating in a smart contract on the platform which stipulates who has access to which information at what price.

Near or distant future?

Circularise is a blockchain start-up working hard to fine-tune its technological solution. The first users are already implementing it. Interior design company MANU, for example, puts the Circularise label on its products. Other stakeholders are also welcome to use Circularise's open source technology. In fact, the founders hope that the entire industry will adopt it.

According to Circularise, technological and non-technological innovations go hand in hand to improve the information flow through the value chain. Customers and consumers are demanding more transparency and better traceability, but the legislator is also pushing companies in this direction. At the same time, blockchain and other developments in the field of digital technology make it technically possible to share information safely.

4. Contraload: efficient data management for the purpose of product pooling

Contraload leases plastic load carriers (e.g. pallets, pallet boxes, containers) and pools them for food, manufacturing and retail companies, among others.

The pooling of pallets unburdens the customer and reduces the ecological footprint

Pooling is a Product-as-a-Service system where customers are loaned the desired quantities of load carriers. After use, the carriers are cleaned, inspected, and repaired if necessary, before re-entering the circuit. Pooling lowers investment costs for customers, allowing them to focus on their core activities. In addition, the responsibility for the equipment is no longer borne by the customers who can always count on high-quality load carriers. Product inspection is crucial to guarantee customers will get the expected functionality and quality. Although they pay per use, customers do make a long-term commitment to the pooling system to ensure it can keep operating steadily.

Why is this a 'green' approach? Because the load carriers are reused, thus extending their lifetime. Efficient pooling also uses fewer load carriers, which means that less virgin material is required. In addition, Contraload strongly focuses on product innovation and circular design: the company's load carriers are modular and repairable, and the pallets are 100% recyclable. Carriers made from a single material (mono-material) facilitate recycling. Within this circular business model, all recycled materials are also reincorporated to manufacture new Contraload load carriers.

Thanks to economies of scale, the logistics chain – delivery and collection – can be organised considerably more efficiently, with a higher intensity of use as a result. In addition, Contraload tracks its load carriers throughout Europe and delivers locally whenever possible to limit the distances covered by its trucks.

Digital solutions ensure efficient pooling

In order to organise such a pooling system efficiently and profitably, it is crucial to know where the load carriers are located, whether they are available and how they can be brought where they need to be. Digital solutions help collect, manage and analyse data on the location, availability and condition of the products.

Contraload uses the online platform Pool-it® to manage the pooling. Customers sign up on the platform to upload or enter transactional data through an interface, and linking their ERP system to it is also an option. For planning and logistics, the platform also provides data on transport, inspections, audits, repairs and new load carriers entering the system, for example. A Business Intelligence module on top of this application allows Contraload to analyse all the transactional data to identify trends and opportunities.

Importance of digital skills

Collecting and managing high-quality data requires more than just technology, however. There are different input methods for different customers, always in line with their specific business processes and capacities. The construction and roll-out of the Pool-it® platform requires a wide range of skills to make the varying implementation processes at the customers (from manual input to ERP interface) user-friendly and keep supporting them. At Contraload, the focus is therefore on building digital skills in all layers of the organisation.

What does the future hold?

Contraload opted for proven technology to set up its digital platform. The experience gained is used to gradually introduce additional, newer technologies that can offer added value with regard to process optimisation and additional customer services. With data and its secure processing gaining in importance, the organisation's IT and data processing department is expanding rapidly. Contraload also entered into various partnerships to closely follow the latest technological developments.

For example, a location monitoring project involving SigFox, LoRa and other networks is currently in its testing phase. Even though these tests are yielding good results, they are also revealing that there are still gaps in the European coverage and that reception problems occur inside some buildings. The protection of this valuable information is another major concern in the development of new applications.

Trackers accurately determine the location of a particular item for example by combining a wireless network, GPS and transmitter mast locations. Wireless connections over short or long distances may be used to that effect:

- short-range: Bluetooth, Near Field Communication (NFC), Radio Frequency Identification (RFID), WiFi, ZigBee and so on;
- wide-range: 4G, LoRa, SigFox, etc.

"Our organisational structure is set to change again because of the IoT: our employees will no longer collect data themselves, and will be able to invest more time in direct customer support based on automatically generated data. So, more focus on the customer, with a larger IT department to make sure data is secure and transparent. In addition, the IoT offers the possibility to add a new layer on top of our existing business model, which may lead to one or more spin-offs. We will see what happens in the coming years."

—Jesse Sels, Co-owner of Contraload

5. Flexty: high-tech characterisation and sorting of glass fragments increases recycling efficiency

The benefits of glass recycling

Using recycled glass fragments (cullet) instead of new raw materials requires 25% less energy consumption in the melting process (as a result of a lower melting point) and therefore contributes to lower fuel costs, fewer emissions and CO_2, a longer lifespan for the glass melting furnace and lower raw material procurement costs. Reason enough to optimise the use of recycled glass.

The challenge for the glass recycling processor is to make pure cullet for the glass industry from the collected (coloured) glass. To do that, various interfering materials must be separated from the glass waste (e.g. pebbles, ceramics, porcelain, thermal glass, leaded glass, plastics).

Hyperspectral cameras detect glass ceramics

Information on the composition of the cullet prior to processing is crucial in ensuring high-quality recycling. For this, Flexty developed a unique inspection method to provide customers – both glass recycling companies and glass reprocessors – with reliable and independent data.

"We are convinced that hyperspectral technology will allow us to keep optimising the quality inspection of glass fragments for our customers in order to facilitate glass recycling and the incorporation of recycled glass in new material. This process is in its final stage and the last practical tests have been planned."

– Jacques van Putten, Director at Flexty

For example, heat-resistant glass – glass ceramics or high-resistant glass – must be removed from the cullet, because the presence of such materials will impact negatively the production process downstream.

This is why Flexty joined forces with imec in 2015. Their common goal was to detect heat-resistant glass among the cullet using hyperspectral cameras and software specially developed for the testing installations.

How does it work?

A hyperspectral camera combines traditional image processing with spectroscopy. For each pixel in the image, the light is split into a series of narrow bands, which makes it possible to measure a spectral signature, unique to every material.

The tint (white, transparent, brownish) of some glass fragments is very similar to the colour of glass ceramics. Consequently, it is virtually impossible to distinguish them with the naked eye. The classic method to test whether a fragment is real glass consists in heating it with a flame and then moistening it or immersing it in water. While a glass fragment will shatter at that moment, glass ceramics will not.

The new technology makes it possible to distinguish glass fragments from glass ceramic pieces much faster on the basis of their visible and near-infrared (VNIR) spectra and then group them with high accuracy in the two main categories. The method also offers rugged reliability as fragments that are partly covered in dirt are also identified.

In short, with hyperspectral imaging, automated and much faster inspection and sorting of glass fragments is possible in the recycling industry.

6. Signify (formerly Philips Lighting): circular economy in practice based on innovative business model and new ICT systems to control lighting

Lighting-as-a-Service: while customers save money, the cycle is closed

In the linear economy – take-make-consume-throw away – selling as many products as possible at the lowest price is an important incentive for manufacturers. In this model, innovation efforts are not aimed at extending the lifetime of a product.

In contrast, Signify, formerly Philips Lighting, wants to develop durable products so that they can remain with the customer longer. In addition to conventional sales, the company is therefore focusing on Lighting-as-a-Service. Under this innovative business model, the customer no longer buys luminaires and lamps and instead subscribes to lighting for a period of 10 years or longer. In addition to the products, the customer gains access to maintenance services, spare parts – also for at least 10 years – and all available upgrades. The model is therefore a full-service. At the end of the contract, the customer may choose to continue to use the lighting installation after a thorough upgrade. If not, Signify will take back the luminaires and give them a second life after they have been refurbished.

The advantages for the customer are clear: without heavy investments, he has up-to-date and energy-efficient lighting that is fully future-proof. In addition to a 10-year warranty, he does not have to take care of the installation's maintenance or upgrades. The customer also knows that there is a sustainable solution for the appliances once he no longer needs them.

What does this Product-as-a-Service model mean for a manufacturer like Signify? While the distance with the end customer gets shorter, contact becomes more holistic. For example, Signify may no longer be dealing with the facility manager only, the financial manager or HR may also be involved. With this approach, Signify builds a long-term relationship with its customers and learns first-hand about their (changing) needs. This increases the company's responsiveness, allowing it to adjust its offer quicker.

"Stability and trust are crucial in the development of a successful circular business strategy. This applies to the relationship between manufacturer and customer, but also to the interaction between the manufacturer and other players in the ecosystem. These may be the installers with whom the manufacturer works more closely under a Product-as-a-Service model, or financial service providers."

— Gert Roeckx, Country Leader Belgium and Luxembourg at Signify

In addition, rethinking product design is crucial: modular components such as drivers and light modules must be designed with a view to easy maintenance and replaceability, which benefits the lifetime of the products. Moreover, the design of the products must be smart-ready. A customer who does not want sensors or connected lighting today should be able to easily integrate these features at a later stage without replacing the whole installation.

Smart is the new green

'Lighting beyond illumination', that's how they call it at Signify. Or how it is no longer just about lighting, but also about light as a means of communication (e.g. LiFi: data transmission over light waves), indoor positioning, heat maps and so on. In addition, Signify's ever-smarter products also contribute to energy-efficient and more circular solutions. Programmed lighting ambiences, day and night detection and presence detection make sure the right amount of light is provided at the right time and place. This allows the company to guarantee the lowest possible energy consumption in homes, office buildings, factory buildings or street lighting.

With Lighting-as-a-Service, Signify commits to match a specific lighting output value to a given energy consumption. Connected products equipped with sensors enable monitoring. Better still, for smart products, it is possible to optimise maintenance and plan servicing before a defect occurs. Smart devices also store information about usage behaviour, the occurrence of wear and so on. This type of automatically generated data from the use phase can be leveraged to improve the design of the next-generation products.

To summarise, by combining an innovative business model – where providing a service over a certain period of time is more important than the product itself – and new ICT systems for the control of lighting, Signify has managed to put the circular economy into practice. The circular Lighting-as-a-Service contract that the company concluded in 2017 with Kortrijk city library was the first of its kind in Belgium. The worldwide premiere took place at Schiphol Airport in the Netherlands. Since then, Signify has concluded other Lighting-as-a-Service contracts with, among others, Destelbergen library and Antwerp Management School.
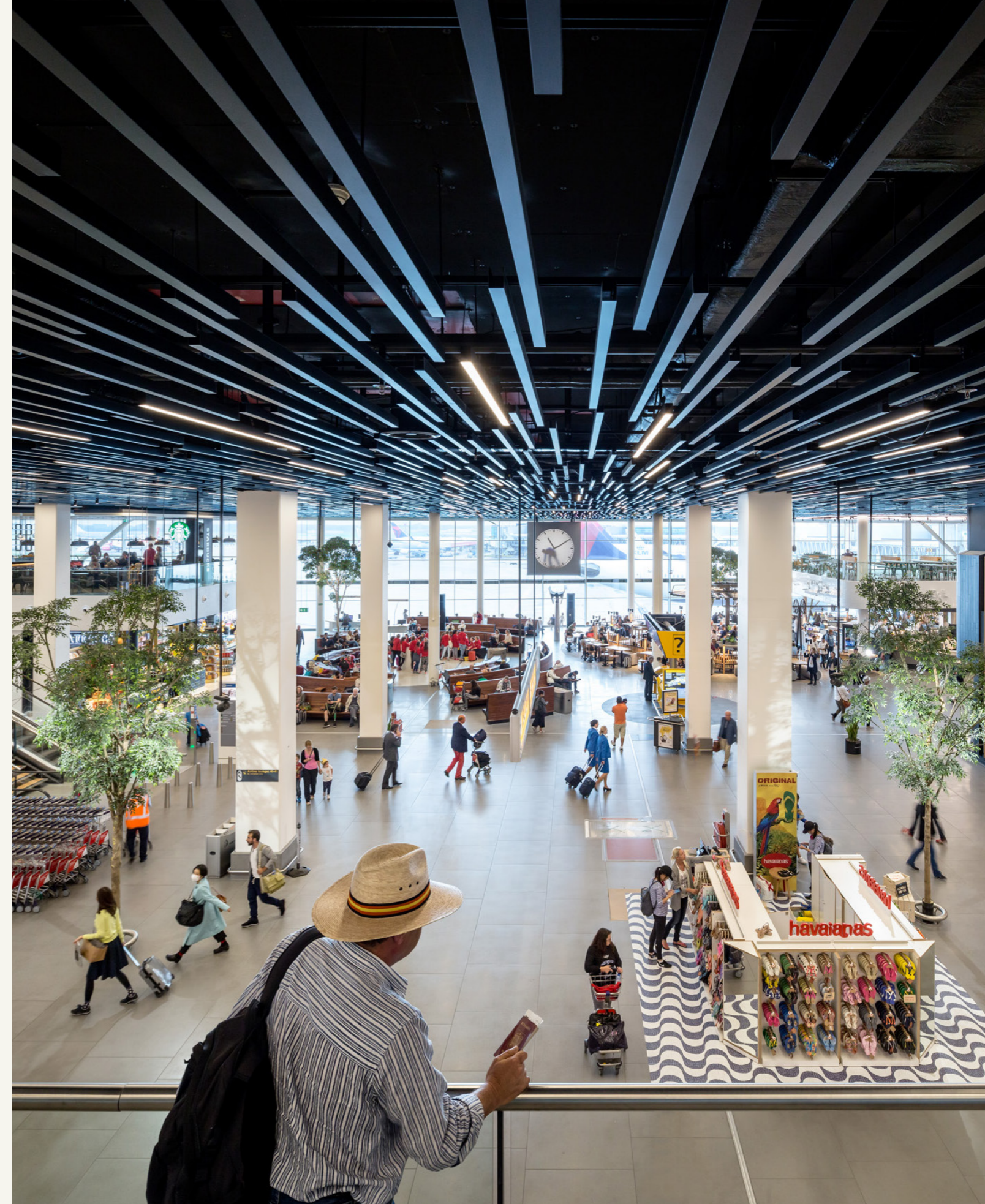
7. SUEZ: advanced waste characterisation with multi-sensor data[6]

Waste characterisation 2.0

Due to the difficulty in measuring the quality of the materials contained, many waste streams are sub-optimally recycled at present. SUEZ tested on mixed plastics and demolition and construction residues a characterisation device developed by VITO that identifies every single particle in the waste. A subsequent stage will involve testing with bottom ash. In time, the new technology will help separate and recover waste streams more efficiently.

Identification of waste particles

Manual waste sorting is expensive and delivers limited information on the quality of the reusable materials. The characterisation technology is able to identify all kinds of waste particles which it captures in the form of a digital twin, i.e. a digital image. The waste is placed on a conveyor belt and screened by X-rays, a 3D laser scanner and a colour camera. Using self-learning algorithms and data science, the device identifies the individual particles and assigns numerous parameters to them, such as size, mass, shape, material, texture, and so forth. This process helps create a digital twin from a physical waste mountain.

Digital twin

Such a digital image provides a lot of useful information. How much metal does the construction and demolition waste still contain? Which metals exactly? How big are the metal particles and what shape do they have? Intelligent technology allows the device to keep learning and recognise more and more types of waste and parameters. This information is useful to improve existing recycling processes and guarantee the quality of recycled materials. Over time, characterisation technology can also help to develop completely new recycling processes by means of simulations.

> **Digital twin:** a virtual image of a product, machine or system. A dynamic software model uses sensor data to better understand a physical object or system. Furthermore, the digital twin can be used to simulate how a product, machine or system will behave in different circumstances: upgrades, adjusted parameter settings, etc. This makes it possible to reduce the risks associated with such actions in the real world.

Paper — Glass — Non Ferro — Wood — Stones — Ferro

© 2018 VITO

[6] This section describes activities that were carried out in the context of the MIP-ICON project 'Characterise-to-sort' by X-Ray Engineering, Suez, Van Hees Metalen, VITO and UGent.

8. Televic Rail: smarter approach to maintenance through machine connection

Technology company Televic Rail designs and produces communication systems for rolling stock, including passenger information and monitoring systems for bogies. More than 25,000 rail vehicles worldwide are now equipped with Televic Rail products.

Connect and collect
Over the years, Televic Rail equipped its train wagons and bogies with sensors. The company also designed a considerable number of rail-specific sensors to monitor the condition of tracks, bearings, stability and the 'health' of the train bogies. In fact, some are mounted on trains that reach speeds of almost 400 km per hour in often harsh environments.

Together with imec, Televic developed an innovative and future-proof hardware and software platform that addresses the specific requirements for all different sensor applications[7]. This allows the company to monitor the condition and safety of its trains at fleet level and offer qualitative calculation and storage options in a compact housing, with optional battery power and wireless connectivity.

"On-board sensor systems are becoming increasingly complex. And because it is becoming easier and cheaper to produce them, more and more are being used: we jumped from 3 or 4 per coach to 50."

— Dirk Van Den Wouwer, R&D Manager at Televic Rail

[7] https://www.televic-rail.com/en/innovation/cosamira-2016-2017
[8] https://www.imec-int.com/en/what-we-offer/research-portfolio/dyversify

Detect and predict
In collaboration with imec, Televic Rail has been exploring new applications to mine the exponentially growing volume of generated sensor data[8]. Data analytics can be applied by sending the sensor data to a scalable cloud solution. The sensor data is then translated into meaningful data to make operational decisions. The latest technologies in cloud-based, scalable and reliable processing and storage have now found their way into working railway applications.

Visualise and proceed to action
The sensors collect data on a variety of parameters, including component temperature, vibrations, speed, acceleration and load on the metal structure of the train. Research into the collection and presentation of this key information will help Televic Rail to provide an optimal tool for predictive maintenance. And that is crucial for train operators: if they can remotely assess what is wrong with a train, they can immediately send it to a repair yard where the right mechanics, spare parts and tools will be present. As a result, downtime will be minimised and the lifetime of train carriages will be extended.

9. TVH: preventive maintenance for 15,000 rental forklifts and scissor lifts thanks to the IoT

TVH rents and sells forklifts, aerial work platforms, sweepers and scrubbers, loading ramps, farm tractors, etc. In addition, the company – often as an OEM (original equipment manufacturer) preferred partner – supplies spare parts, carries out repairs and maintenance on machines and provides technical training. How does TVH contribute to the circular economy and, in so doing, how does it generate business and added value for its customers?

Parts harvesting
TVH purchases end-of-life forklifts and scissor lifts to recover their valuable parts. In other words, TVH focuses on parts harvesting. Once disassembled, cleaned, inspected and possibly repaired and upgraded, the parts are re-marketed. TVH has a large remanufacturing workshop and a lot of expertise in the field of reverse engineering.

Through parts harvesting, product components get a useful second life and TVH gains access to a broader customer base. In addition to companies looking for a more affordable spare part that has already been used, this group of customers includes companies seeking fast service. Partly thanks to its remanufacturing activities, TVH can guarantee very short delivery times (24 hours within Europe).

Machine-as-a-Service
Investment costs for the type of industrial equipment that TVH supplies keep increasing. Moreover, strong variations in the intensity of use can make a purchase economically unprofitable: all too often, expensive machines remain idle. Through its leasing model, TVH can offer customers access to excellent forklifts, scissor lifts or other machines, without them having to pre-finance the equipment. In addition, the burden of maintenance, repairs and upgrades is taken from them.

Intelligent fleet management makes sure the machines can be used efficiently by different customers. When compared with a scenario where every customer buys its own machine separately, for instance, the leasing model can deliver as much functionality with fewer machines. In addition, TVH closely monitors the machines on site and performs predictive maintenance. This approach extends the lifespan of the machines and contributes to a significant reduction in the environmental impact.

How does digital technology support TVH in its activities? Many supporting processes are required and all kinds of data need to be managed to guarantee the service level and to repair and remanufacture machines efficiently:

- identification, storage and management of (new and used) spare parts;
- identification, traceability and follow-up of machines at customers;
- extensive web shop and customer support activities.

Digital technology facilitates each of these processes. TVH follows the business Innovation through IT (BI²T) method to that effect. In the past, strategies consisting in aligning business software (e.g. ERP, CRM) were viewed as an end in themselves. However, TVH is convinced that a merger of business and IT is indispensable. In the BI²T approach, technological and business knowledge and expertise are brought together in an environment that drives innovation. This means that digital technology has to make a direct contribution to more efficient and robust business processes.

Here are a few examples:
- The warehouse management system ensures just-in-time (JIT) deliveries to customers worldwide the next business day. This in-house warehouse management system makes it possible to process 7,000 orders (28,000 picking lines) per day. The operation of the warehouse is a textbook example of operational excellence and could only be achieved by combining the knowledge of warehouse operators, business analysts and experts in digital technologies. Additional mobile applications are being developed for customers, including barcode scanning and geolocation, to ensure they can get the support they need more rapidly.
- Steps were also taken to increase the robustness of the system. In a fully virtual environment, two clustered data centres and their backups can ensure maximum uptime. The fully redundant infrastructure gives the many virtual machines the opportunity to extract data from one of the clustered databases, even if one of them is not operational (e.g. during maintenance or an upgrade). This large temporary memory therefore always guarantees fast data access. In the meantime, a hybrid model is being built to allow these virtual machines to operate in the cloud as well as on the local infrastructure.
- In cooperation with a partner, an e-commerce website was built from TVH's own framework and based on Quarix and Wicket.
- Thanks to the IoT, TVH knows the exact location and condition of each of its 15,000 rental forklifts and scissor lifts. Finally, the switch from reactive to predictive maintenance is now possible, resulting in less downtime for the customer.

Predictive analytics is the use of data, statistical algorithms, machine learning technology and artificial intelligence to predict future outcomes based on historical data.

TVH implements a smart mix of mature, proven and newer technologies to keep improving the quality and speed of its service.

The integration of business and digital innovation is only possible if the organisation also endeavours to broaden knowledge across the traditional department boundaries and work domains (e.g. organisation of production, deployment of digital technologies, competency management, customer needs, communication). In this context, the organisational structure and learning culture are crucial. Initiatives come from all organisational levels and are implemented in small, multidisciplinary teams. TVH encourages a hands-on approach, where experimenting is allowed.

10. WillFill: remote diagnosis of cooling emulsions for machine tools

WillFill manufactures and sells monitoring and management systems for cooling emulsions used in metal cutting. The cooling emulsion – a mixture of water and oil – is used in a closed circuit to cool the cutting tools and remove chips from the workpiece. The WillFill device measures, registers, analyses and controls the cooling emulsion to ensure that the machines can keep working optimally and last longer.

"In practice, with periodic tasks such as measuring, (re)filling and conditioning being taken over by the device, there are fewer cases of overfill and thus a reduction in unnecessary cleaning work. The autonomous checking and management of the emulsion level and condition facilitates the machine operator's work, who in turn gains in reliability."

— Pieter Dierickx, Co-owner of WillFill

WillFill equipment contributes to extending the lifetime of emulsions, optimal use of machine tools and preventive maintenance. In addition, the devices themselves have also been designed to last.

- Cooling emulsions and cutting tools last longer
The WillFill devices enable the user to monitor the quality of the cooling emulsions, and keep using them longer as a result. Instead of replacing the emulsions at pre-set intervals, the refills occur precisely at the moment when predefined threshold values are exceeded. The lifetime of the cutting tool is also improved by optimally managing the emulsion parameters at all time.

- The cutting machine works better
Sensors in the device measure concentration, pH, conductivity, water hardness, liquid level and so on. Up to seven values with an impact on the quality management of the metalworking emulsion are registered and stored, even outside production hours. The data is processed in the device and used to control, among other things, the self-priming oil pump or water supply. The device is therefore able to control and adjust the emulsion level and condition autonomously, or if necessary, alert the user.

- Optimised maintenance
It is possible to set quality limit values in order to schedule servicing and therefore prevent contamnation of the metalworking emulsion. WillFill will also detect an abnormal coolant level indicative of a possible malfunction or leakage in the connected machine. An online dashboard is used for off-site monitoring.

- Circular design
Furthermore, the WillFill device itself has been designed and built from high-quality materials in such a way that the components can be reused after the first life and can be recycled at end-of-life. The products can also be upgraded and repaired remotely. The installed devices keep receiving software updates over a wireless connection, a feature made possible by a two-way communication between device and manufacturer. For example, the manufacturer can perform online error detection and install a custom firmware after analysis.

Reusing parts is a possible next step. The integration of different functions (e.g. sensors, actuators, data analysis, reporting) and the need for a robust design causes the cost of a product to rise. Hence the interest in recovering parts of discarded devices in one way or another, through parts harvesting for instance.

How does the customer benefit?

From the user's perspective, the challenge is to integrate the management of the cutting machine cooling emulsions into daily production and maintenance activities. The WillFill devices relieve the customer from the burden of managing the cooling emulsions. In addition to extending the lifetime of the emulsions and the cutting tool, the device provides added value by taking over a number of periodic tasks: measuring, (re)filling, reporting, conditioning, etc. Analyses based on aggregated data from different machines in the same machinery stock are also possible. This allows the customer to compare machines or processes, or gain insight into the impact on the emulsion consumption of, for example, tooling changes, machined materials or the selected oil.

How does the technology stack actually look like in a WillFill device?

- WillFill is fitted with sensors which measure the oil-water ratio, pH, temperature, conductivity, level, water and oil consumption.
- The actuators consist of a self-priming oil pump, RGBT LED status, alarm buzzer and EM valve for water supply.
- The device has a PID controller that allows autonomous tuning.
- E-mail notifications for each event.
- Communication via 4G, WiFi or LAN connection, buzzer, etc. allowing the user to monitor the reporting on an online dashboard.

The technology used is mature.

A good business model for the marketing of new technologies

The WillFill technology challenges many years of machining habits. The company is still looking for the ideal business model: sales, rental or leasing? For which customer segments? On-site or online service? Etc. The technological and functional capabilities of the device are but one aspect of this project.

11. 3E: cost-efficient and lifetime-extending maintenance enabled by digital technologies

It should be possible to significantly reduce the operating and maintenance costs of renewable energy generation (e.g. using wind turbines) to ensure they remain competitive compared to other energy sources. Many developers, operators and owners of wind turbine farms in Belgium and abroad are relying on the software and services of 3E to achieve those goals. This resulted specifically in SynaptiQ, a platform developed to monitor the performance of the wind turbines and allow predictive maintenance.

Based on collected data about, among other things, load, voltage and efficiency, the platform analyses the performance and availability of each wind turbine. Then, by comparing the measured behaviour with the expected one, it determines whether the behaviour is abnormal. If this is the case, SynaptiQ provides insight into the possible causes of the problem. The data is then used to plan maintenance activities to tackle the causes of the substandard performance as quickly as possible, or prevent a certain (sub) component from failing.

How does it work in practice?
The control systems of wind turbines use a large number of sensors and indicators to measure behaviour in real time. These data streams are forwarded to a remote system which processes the data and intervenes where necessary. SynaptiQ dissects the streaming data and runs predictive algorithms. The system implements AI methods to detect whether a wind turbine is underperforming.

Artifical intelligence is software that is capable of reasoning and independently solving a wide range of problems.

Rapid progress
Until recently, the continuous monitoring of wind turbines was quite a challenge. First, each turbine contains millions of (sub)components that must be equipped with sensors. Integrating those sensors was expensive, so was providing the power supply they need to operate. Secondly, all those sensors generated such a large and complex data stream that it was impossible to analyse it in real time. In addition to the mass production of low-cost, energy-efficient sensors, improved communication technologies – such as the upcoming roll-out of 5G – will provide the necessary network support to cope with the huge data streams, with less delay and a higher transmission speed between turbine and platform as a result. This will speed up the processing of measurement data – from the wind turbines to the digital platform – and analysed data – from the platform to the turbine.

3E is currently working with Sirris on a method to extend the life of wind turbines on the basis of advanced predictive analytics[9].

12. Waste containers: more efficient logistics with filling level sensors

In the collection of waste materials, smart transport planning is crucial. This is why different waste collectors use innovative systems to tackle waste logistics more efficiently and sustainably.

What is the goal?
Containers – bottle banks, clothes banks, etc. – are currently emptied according to fixed routes. Waste collectors schedule their collection rounds at regular intervals. As a result, some containers are emptied too quickly, while others become so full that the waste is dumped next to it.

Telemetry is changing this: various parameters (e.g. filling level) can be measured remotely and transmitted over (wireless) telecommunication networks. And when dispatching can monitor the filling level remotely over time, it becomes also possible to predict when the container may or must be emptied. This allows the waste collector to optimise collection rounds.

This system has many advantages: when containers are fitted with a sensor, the time per order decreases, the service level rises due to the timely emptying, the number of rounds decreases and the weight per container emptying rises.

There are, however, some shortcomings. Malfunctions may occur, which would force the operator to estimate the next collection anyway. In addition, waste is not a liquid: it does not always accumulate homogeneously and can cave in. Every day, multiple measurements are therefore required to weed out anomalies. Finally, there may be a perception difference between customer and sensor data about when a container is full.

Which technologies are used?
- Ultrasonic sensor technology works with every type of waste: residual waste, organic waste, paper, glass, textile and metal waste. It is mainly used for underground containers and bottle banks.
- Infrared sensor technology is used for, among other things, the collection of batteries (by Bebat) in supermarkets. However, this sensor type is unsuitable for use outdoors (where there is moisture for instance).

- SUEZ and Vanheede, among other companies, have run pilot projects involving the use of a multi-beam LED scanner to monitor the filling level of skips and wheelie containers.
- Several partners and suppliers can contribute: imec, Siemens, SICK, TWS, Aphatronics, Pepperl+Fuchs, Dekimo, Enevo, SmartBin, Sigrenea, and many more.

The savings in terms of waste collection mileage usually outweigh the investment costs associated with the sensor installation and smart data monitoring, which often adds credit to the business case.

Sources

Agoria & Sirris, White Paper 'Circulaire economie: hoe onze technologiebedrijven nieuwe duurzame bedrijfsmodellen toepassen', 2017, https://www.agoria.be/nl/Whitepaper-Circulaire-economie.

Sirris & Agoria, White paper 'The circular economy, creating new value', 2017, https://www.sirris.be/nl/whitepaper-circulaire-economie.

Alexander Osterwalder & Yves Peigneur, Value Proposition Design, Wiley, 2015.

Anna Swenson & Paul Quickert, Cisco Services Repair and the Circular Economy, Cisco, 2017.

Ash Maurya, Running Lean: Iterate from Plan A to a Plan That Works, O'Reilly, 2012.

BS 8001: 2017 Framework for implementing the principles of the circular economy in organisations – Guide.

Ellen MacArthur Foundation, Intelligent assets. Unlocking the circular economy potential, 2016.

Eris Ries, The Lean Startup, Crown Publishing Group, 2011.

Gartner IT Glossary, https://www.gartner.com/it-glossary.

Gianmarco Bressanelli et al., Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies, Sustainability 2018, 10, 639.

Henning Wilts & Holger Berg, The digital circular economy: can the digital transformation pave the way for resource-efficient materials cycles? in brief 04e/2017, Wuppertal Institute.
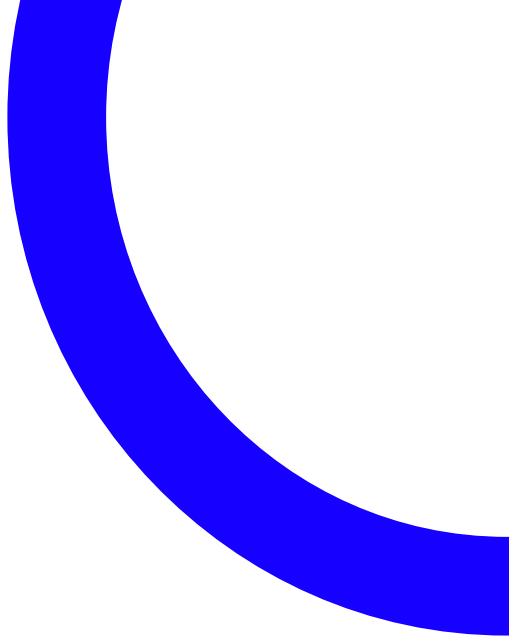
Internet of Things Nederland, https://internetofthingsnederland.nl/e-book-internet-of-things-nederland/.

Johanna Kallio et al., A Tool Rental Service Scenario. IoT technologies enabling a circular economy business model, IARIA, 2017.

Chamber of Commerce, Netherlands, Internet of Things: slimme en internet-verbonden producten en diensten, 2014, www.kvk.nl/iot.

Michael E. Porter and James E. Heppelmann, How Smart, Connected Products Are Transforming Competition, Harvard Business Review, November 2014.

Sofie Narinx, Circular Economy Insights. Disruptive technology to optimise reuse, IBM, presentation at CSR Europe conference, 28 October 2015.