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THE THREE SUCCESS FACTORS FOR THE FACTORY OF THE FUTURE

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INTRODUCTION

What will the future bring?

The European process and manufacturing industry remains a global leader in terms of the quality of its end products and the reliability and efficiency of its factories. But this leading position is by no means guaranteed, as emerging economies such as in Asia are rapidly closing the gap with regard to process optimization, innovation and the sustainability of factory installations.

What does this mean for Europe's industry and manufacturers in sectors such as food, chemicals, pharmaceuticals, oil and gas, and energy? How can they retain their competitive advantage, today and in the near and distant future? Three to five years from now, what will be the basis of their success and how will this shape their future factories?

In other words:

What are the key success factors for the factory of the future?

This white paper is an exploration of these success factors. With contributions from Tebodin specialists and engineers we have defined three main pillars of successful exploitation of the (processing) factory of the near future. In Chapter 1 we will discuss Industry 4.0, the next step in the digitalization of processes and the connecting and sharing of process data. The second chapter will focus on sustainability, the green aspects of the factory of the future. More specifically, we will discuss a circular production process and methods of saving and generating energy in the near future. The third success factor (Chapter 3) is flexibility, or: how to successfully respond to rapidly changing market demands and conditions?



The factory of the future is **connected** to the utmost degree

Our industrialized society has been through three previous revolutions: water and steam power (18th century), electricity and mass production (19th century) and electronics and computers (20th century). Industry 4.0 is the fourth revolution, which we are now in the middle of, with the Industrial Internet of Things (IIoT) and machine-to-machine (M2M) communication as its main pillars.

To a large extent, the competitive potential of the factory of the future depends on its level of 'connectedness'. In other words: how successful a factory is in collecting, sharing, communicating and analyzing information. This, after all, is what gives the factory of the future its cutting edge in reliability, efficiency and the quality of its end products – three elements that define the return of investment in a factory.

Industry 4.0, the ultimate catalyst

One of the most important objectives of the factory of the future, therefore, is to connect each and every aspect of the primary (production) process. In real time, and 24/7. New, modern factories have already begun the technical integration of systems that transcend horizontal processes, geographical boundaries, hierarchies and value chains. Industry 4.0 would seem to be the ultimate catalyst in this respect, with the Internet of Things as a driving force.

Industry 4.0 as defined in PwC's 2016 Global Industry 4.0 Survey¹

Industry 4.0 focuses on the end-to-end digitization of all physical assets in order to integrate them into digital ecosystems with value chain partners. The ability to seamlessly integrate, analyze and communicate data from these ecosystems underpins the gains promised by Industry 4.0.

Industry 4.0 is not just about digitization and networks of horizontal and vertical value chains, but also about the innovation of products and services and the implementation of new and often disruptive business models.

Faster decisions, greater control

This means that data on process progression and optimization, output, inventory, deployability of equipment and personnel, (future) downtime of a factory and market developments will no longer be segregated, but shared for the purpose of optimization and analysis. Moreover, information will be obtained from the supply chain, for instance relating to what needs to be produced and what quantities will be required. Installations may be enabled to adapt to such information autonomously. All of this will offer immense opportunities to optimize production facilities and processes, but also to enable factory workers and management to gain greater control, speed up the decision-making process, make smarter choices and ultimately be able to respond more efficiently to the immediate needs of the market.

This is why the factory of the future is connected to the utmost degree.

How? By using smart sensors, machine-to-machine communication, mobile devices, cloud computing, real-time analyses, robots, cameras and microphones (to monitor equipment frequencies) and big data analytics. In the factory of the future, installations and equipment are fitted with more sensors than ever. ~~In its 2014 white paper, Cisco estimated that in 2015 there would be 25 billion connected devices, compared to 7.2 billion people and double that number of devices by 2020.~~ This is creating a much stronger connection between the factory floor and a manufacturer's ecosystem and will result in closer collaboration between engineers, management and contract manufacturers.

Connected > improved performance

Factories that get the integration of networks right show much better performance than those that fall behind, says Aberdeen Group. The UK researchers reached this

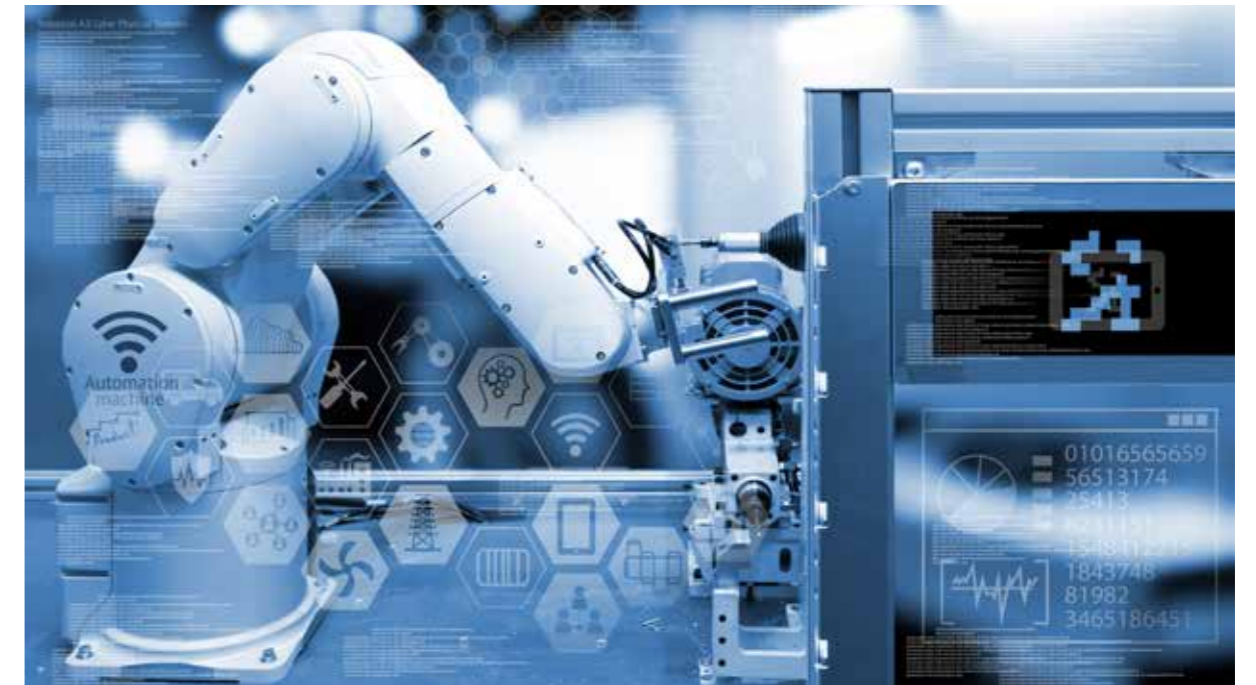
conclusion after comparing manufacturers with similar levels (67%) of connected networks in their production facilities. Aberdeen Group categorized manufacturers according to the level of their ability to exploit the opportunities of their connected networks: 20% scored as best-in-class, half (50%) were at middle level and 30% at low level. Best-in-class factories showed uptimes of 99.91%, meaning they were down no more than eight hours per year. Mid-level factories were down four times as long (36 hours) and at the low end downtime could even be as high as 135 hours per year. Similarly, the best in class scored much higher in overall equipment effectiveness (OEE): 90% compared to 80% (middle) and 60% (low).

Aberdeen Group's research shows that Industry 4.0 plays a crucial role in the optimization of production processes. The integration of systems, however, requires a safe and robust IT infrastructure. This structure needs to be taken into account even before the start of the design phase of the factory of the future, ~~says Maurice Houben, Director Strategy & Innovation at Tebodin. He anticipates that data will be the driving force behind the factory of the future.~~

IT structure, the central nervous system of the factory of the future

'In its visual appearance, the factory of the future is probably not much different from today's factories. The differences are in the way it is operated, automated and digitalized. Many smart technologies are applied as early as in the design stage to ensure that the factory can handle its raw materials more economically, that it is more accurate in its energy consumption and more aware of its state of maintenance.'

This requires specialist IT expertise and a thorough understanding of the factory's branch of industry. ~~Houben:~~ 'Branch-specific engineers play a crucial part in the design of the factory of the future, as they know their clients' requirements as well as the mechanical and instrumental aspects of installations. Very importantly, this enables them to recognize which data are truly relevant in the production process.'



~~Houben compares the factory of the future to the human body: its pipes are like the veins, the tanks and reactors are like the organs and the data streams are like 'the nerve paths of the factory'.~~ That makes the place where the data are combined the factory's central nervous system. ~~As Houben sees it,~~ this is where in the future we'll see automatic generation of reflexes and instincts.

Data feedback reduces investment risk

'With the help of process data and pattern recognition it will be possible to much more accurately predict the behavior of a factory, how it will perform and what it will produce. The data we collect will be fed back into the factory in order to further increase efficiency. This will help to create algorithms and some form of artificial intelligence (AI) for even further optimization of installations.' In this way, data will also contribute to the increase of investment security, an aspect that in the European industrial sector, where margins are under pressure, continues to gain in importance. Here, the motto applies: the greater the reliability, efficiency and quality of a factory installation, the more justifiable the investment.

The fourth revolution is far from complete. It's hardly even started. Experts estimate that it will take at least two decades for Industry 4.0 to reach full maturity. At the same time, no one is underestimating its importance or its impact. Specialists agree that this new revolution will shake the foundations of almost every industry. This realization underlines the importance of starting the integration of the Internet of Things in the factory of the future's foundation: the design.



The factory of the future is powered by renewable energy and produces no waste (circular production process)

In the factory of the future, sustainability is more than an ambition, a CSR program or a lofty slogan. Much more. In the factory of the future, sustainability is an integral part of business operations. Sustainability is a key consideration in the design of the factory and its installations.

In this chapter we will explore two specific aspects of sustainability in the factory of the future. First, the production process, or, to be precise, the carbon footprint of the production process. In the best possible scenario this (ecological) footprint of the factory of the future is a positive one. We will explain which steps can be taken (and how) to make the production process more circular, both vertically and horizontally.

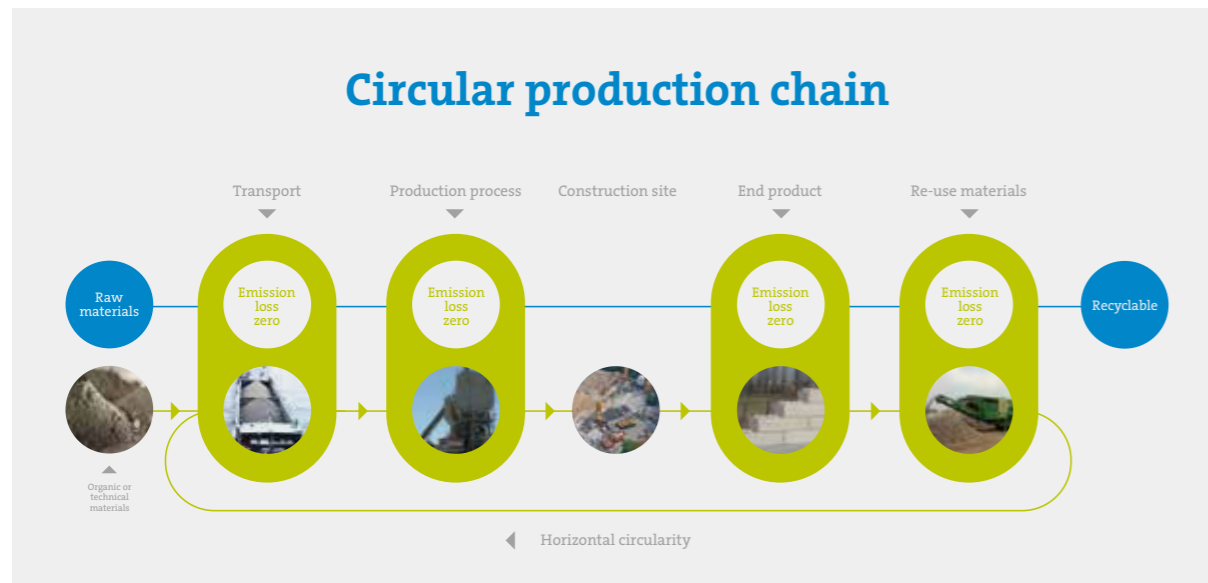
Mapping the supply chain

The first step in reducing a carbon footprint is to obtain a thorough understanding of the footprint. This is a complex process, as manufacturers in sectors such as chemicals, pharmaceuticals and food often operate in extensive and globally connected production chains. Tebodin uses a method developed together with EcoChain Technologies to map the carbon footprint of a company that divides the total production chain into five segments: raw materials, transport, production, end product and re-use of materials.

When in each of these segments emission loss (loss of raw materials into the air, water or soil or as waste) is avoided or when residual materials are used as a raw material in a different production chain, the result is called vertical circularity.

Horizontal circularity is about preventing waste at the end of a product life cycle by designing products with an eye on re-use. The factory of the future will therefore always aim to ultimately put its end product at the start of a new chain. In other words: the end product should (to a large extent) be suitable for use as a raw material in a new production process. If this is achieved, this is called horizontal circularity.

For a factory to organize this correctly, ~~says Mariska van Dalen, Senior Sustainability Consultant at Tebodin,~~ it needs to understand the entire cycle and to make visible the costs of raw materials, energy, water, waste processing and the environmental impact expressed in euros. 'This way you'll



know which elements have the greatest impact and where the chain is broken. With that knowledge, you'll be able to close the chain with a substantiated business case.¹

Raw materials

In creating circularity, an important step is to seek connections with other production chains, ~~says Van Dalen~~.² 'One of the quick wins, which many companies are unaware of, is that one manufacturer's waste can be another one's raw material. If you're not bound by contractual stipulations regarding waste disposal you might be able to create circularity today by turning your waste streams into a raw material for a nearby company.'³ Another solution could be to choose different and more environment-friendly raw materials to make your product, ideally ones you can purchase from a local manufacturer.

Heat distribution networks and transport

Another contribution to reducing the carbon footprint of the production chain can be achieved by using residual heat via heat distribution networks. 'The industrial sector is a major consumer of heat and is therefore potentially (in the long term) both a major customer of heat grids and a major

supplier of residual heat to these same grids', says PLB, the Netherlands Environmental Assessment Agency, in its ~~2017 policy study~~³ into climate neutral heat grids in the Netherlands. PLB anticipates a shift in industrial demand for heat in the next few years from high-temperature (HT) to low-temperature heat (LT). The challenge that industry faces is to redesign processes in order to reduce process temperatures in sectors such as chemicals, oil and gas, food and pharmaceuticals. As temperatures go down, electrification of the industrial sector isn't far around the corner (see section Electrification, next page).

In its study, PLB poses that it will take a departure from the trend to achieve substantial reductions of emissions in the energy-intensive industries. LT will play an important part, as further reductions will depend on, among other things, measures to improve energy efficiency, such as the use of heat grids.

⁴'With regard to heat, the factory of the future greatly reduces its impact on the environment through connections with other manufacturers', ~~anticipates Van Dalen~~.⁵ 'In combination with sustainable means of transportation – think electric vehicles, massive reductions of road transport and maximization of inland navigation – this takes the production chain several steps closer to vertical and horizontal circularity.

Commitment to renewable energy

Crucial to achieving this goal is the total commitment to using green, renewable energy. Not just in operations (power supply) but also in the generation of industrial heat (electrification). In addition, the factory of the future will succeed in optimizing energy efficiency as it reduces consumption with the use of smart software (algorithms). Among the most common types of renewable energy, the ones with the greatest potential (depending on the sector) are wind, solar and biomass-generated energy.

Electrification

The increased availability of cheap green energy ~~will~~ have a major impact on the factory of the future, ~~anticipates Stef Clevers, Manager Engineering Industrial & Energy at Tebodin~~.⁶ 'Electrification is the new buzzword in the industrial sector. Almost everyone is convinced that within five years from now electricity will be much more sustainable and prices will continue to decrease.'⁷

This will result in new business models that take advantage of the possibility to use electricity for other purposes than just the operational ones (power supply), such as the generation of heat for industrial processes. In the factory of the future this will be done with large-scale heat pumps and electric boilers. As soon as this technology proves its value it will start acting as a catalyst in the process industry.⁸

Saving with algorithms

In addition to the sustainable generation of heat, the factory of the future will continue the trend of reducing energy consumption, but its methods will be more advanced. ~~Clevers says that~~ within a few years this will involve the use of a 'connected production process'.⁹ 'Big data and data analytics will result in new insights into energy efficiency, because they will enable us to look deeper into the factory, down to the micro level.'¹⁰ Effectively, this will entail a mapping of the production process's energy chain. With the obtained data, smart

software can find connections that would previously have stayed undetected. ~~Clevers~~:¹¹ 'Through continuous monitoring of real-time data it's possible to connect variables such as raw materials consumption, outside temperatures and production output. Consecutively, the software is able to recognize patterns and create algorithms for optimization.'¹²



SUCCESS FACTOR 3

The factory of the future is flexible in every sense

The European bulk industry is under pressure. Other parts of the world (Asia, the US, the Middle East) are overtaking the 'old continent' on the basis of cheaper labor, cheaper energy and more direct access to raw materials. Of course, the numbers vary per sector (chemicals, food, pharmaceuticals), as do the ways in which investments find their destinations outside of Europe, but the overall conclusion seems clear: the prospects of bulk production for the European (process) industry sector depend on a high level of reliability and quality, both in terms of operations and the delivered product.

The factory with the greatest business potential and the best chance of sustainable success is one that is smaller and scalable, and chooses innovative, specialty products. Its products are of the highest quality and are produced locally and sustainably. At the same time, thanks to a compact production and supply chain, these products can be marketed relatively quickly. The use of customer feedback (user data after digitalization) will lead to further improvements in products and services. There is a world to be gained here. At this point, on average only 15%⁴ of all available data is actually utilized.

Finding the perfect balance

~~According to Nick de Koning, Director Global Pharmaceutical Projects at Tebodin,~~ what it comes down to in the factory of the future is 'a perfect balance between market demand, fulfillment of quality requirements, efficiency in production, reliability in supply, minimization of inventories and speed in delivery'. ~~He can see this~~ happening already in the pharmaceutical sector. 'Increasingly, major manufacturers are working with contract manufacturing organizations (CMOs) and contract development manufacturing organizations (CDMOs) who supply them with specialty products. The strength of these

smaller, flexible plants lies in the fact that they are able to produce on demand, are operated by professionals, have a high capacity utilization and are reliable suppliers of high-quality specialty products.'

~~De Koning is convinced~~ the relatively high investment in a flexible factory is economically justifiable because of the high quality of the products, the market value they represent and the ability to innovate and to up or downscale. Other factors are the high level of reliability and cost efficiency of a production facility, qualities that he believes will determine the future success of the European (process) industry sector.

Flexibility is a must

The necessity of flexibility in operations flows from the increased demand for specialty or even personalized products in sectors such as the pharmaceutical and food industry (clinical nutrition, food supplements, sports beverages). In addition, product life cycles are growing shorter, which puts greater pressure on innovation. The factory of the future will therefore have to be flexible in a number of ways.

Flexibility will be required in terms of equipment and installations, production capacity and the types of products that can be produced, but also in terms of efficient use of raw materials and especially the availability and utilization of digital information from the production process. A plant with a flexible production capacity will be able to quickly launch into local markets and profit from emerging economies without necessarily having to rely on major investments. In case of growth, it will be easy to upscale modularly. Flexibility in product selection enables the factory of the future to quickly respond to new market demands, while the production of

variations on existing products requires no more than a technological adaptation.

More efficient use of raw materials

If a factory and its R&D department want to be flexible in innovation, the important drivers are knowledge and experience. It's no coincidence that these are the qualities that are still the hallmark of European industry. Flexibility in this area contributes to successful pilots and shorter time to market of new products. As a result, the factory of the future will be able to produce closer to the local market, while innovations will make it possible to monitor and control production from a distance. Increased process efficiency and a reduction of waste and by-products will reduce the consumption of raw materials.

Autonomy

Previously in this white paper (Chapter 1) we discussed connectivity as a success factor of the factory of the future. Connectivity and flexibility are inseparable: a factory's level of connectedness is a major determiner of its level of flexibility.

Connectivity will make the factory of the future more autonomous than ever, enabling it to more rapidly deliver special products and batches. Production modules can be connected according to the needs of the moment while equipment is easier to adjust, monitor and modularize. The factory of the future is no longer a static configuration of components, but rather a collection of modules (even including mobile equipment), which, depending on supply and demand, work together in the most efficient and competitive configuration.

This is why the factory of the future is connected, green and flexible in every sense.

The factory of the future? Better sooner than later

Assessing the strengths of the European process and manufacturing industry, we see that it still holds a few strong trumps: experience, knowledge, innovative ability, capital and technology. However, if Europe wants to maintain its position in sectors such as chemicals, food, pharmaceuticals, oil and gas, and energy, it will have to play those trumps smart and innovatively in the next few years. Simply holding on to existing market positions won't be nearly enough for most manufacturers if they want to resist the strong momentum of emerging economies.

Data for stronger connections

In this white paper we have shown how digitalization, sustainability and flexibility are the pillars of success for the factory of the future. These three will enable manufacturers to maintain their advantage in terms of the quality of their end products and the reliability and efficiency of their factories.

What does this mean? In any case it means that factories in the future will be fully committed to the digitalization of their production facilities and processes. Data on process progression and optimization, output, inventories, deployability of equipment and employees, and market developments will no longer be segregated but will be shared for purposes of optimization and analysis. In this way, data can contribute to an increase in investment security. But more than this, the exchange of data will also result in stronger connections between the factory floor, engineers and management, which will ultimately result in a better response to market demands, feedback on products from the market and greater efficiency in delivery.

Electrification

Both in its operational and its industrial processes, the factory of the future is powered (almost) entirely by renewable energy. Solar energy is already a driving force behind electrification, one of the latest phenomena in

industry. Electrification will drive new and disruptive business models as industrial processes driven by electricity allow for different types of design.

The factory of the future will also aim to maximize the return of its end products to the start of the chain. In other words, the (residual waste of an) end product will serve (to a large extent) as a raw material for a new production process. This is called horizontal circularity. Vertical circularity is created by aiming to minimize emission loss (loss of raw materials in the air, water and soil and as residual waste) in the different segments of the production chain.

The final success factor of the factory of the future is flexibility. Especially factories that are smaller, scalable and focused on innovative and specialty products will be able to distinguish themselves. With high-quality products, reliable supply and local production facilities, these factories will be able to successfully and quickly respond to new market demands.

Thanks to high-quality products, the market value they represent and the ability to innovate and to up or downscale, relatively high investments remain economically justifiable – today as well as in the near and more distant future.

¹ 2016 Global Industry 4.0 Survey, 'Industry 4.0: Building the digital enterprise'

² http://www.cisco.com/c/dam/global/en_ca/never-better/pdf/cisco-ind-smart.pdf

³ <http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2017-toekomstbeeld-klimaatneutrale-warmtenetten-in-nederland-1926.pdf>

⁴ <https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/factory-future-industry-4.0.pdf>

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