

## **Contents**

Introduction	3
The identity of the survey	
How much do you know about the 4th industrial revolution?	7
Do you think that the 4th industrial revolution will affect the waste & recycling industry?	9
If your answer in question 8 is "yes" or "somewhat yes", please specify the impact until 2030	11
Assess the impact you expect on the waste management and recycling industry from the following elements	13
Please check the innovations that will be available in 2030.	15
Please rank the following developments in order of their impact on waste management & and recycling in the coming 15 years	17
Which of the following areas will be impacted the most by the 4th industrial revolution? Rating Average out of 7 (7 = most impacted)	19
Do you think that the 4th industrial revolution will make circular economy a reality for most of consumer goods?	21
Please check the areas of development that will happen before 2030 as a consequence of the 4th industrial revolution	23
Please check the areas where you think your organization should invest	25
Instead of conclusions	27

## Introduction

This report presents the results of ISWA's global survey on the impact of the Fourth Industrial Revolution in waste management and recycling, according the opinions and views of more than 1000 members of the industry.

We already live in the transition towards the 4th Industrial Revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society.

The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

Artificial Intelligence, Robots, Drones, Driverless Cars, 3D Printers, Internet of Things and The Revolution of Sensors, Decentralized Energy, DNA Engineering and the Rise of Bio-economy create a new landscape that will reshape manufacturing. It will also reshape waste management and recycling too, redefining the meaning of "waste", creating new technologies, delivering robotic solutions and driverless collection patterns.

The results of the survey demonstrate that although the industry is somehow aware of the change waves ahead, just 14% of the participants consider themselves to be knowledgeable on the 4th Industrial Revolution. In addition, it seems that the depth and the speed of the 4th Industrial Revolution are rather underestimated.

The results also highlight that the participants hope the 4th Industrial Revolution will deliver solutions to several challenges related to waste management, from eco-design to waste prevention and circular economy of plastics.

ISWA will continue to work with its members and partners in order to help the industry to understand, prepare and utilise the advances of the 4th Industrial Revolution for a more sustainable waste management, in each and every country and city. A roadmap for the adaptation of the waste industry to the 4th Industrial Revolution will be the next step in this way.

I hope that the results of this survey will stimulate and inspire the waste management scientists and practitioners to surf on the upcoming wave of change. Because the problem with the 4th Industrial Revolution is that either you surf on it, or it will wipe you out of the tomorrow's business landscape.



Antonis Mavropoulos ISWA President

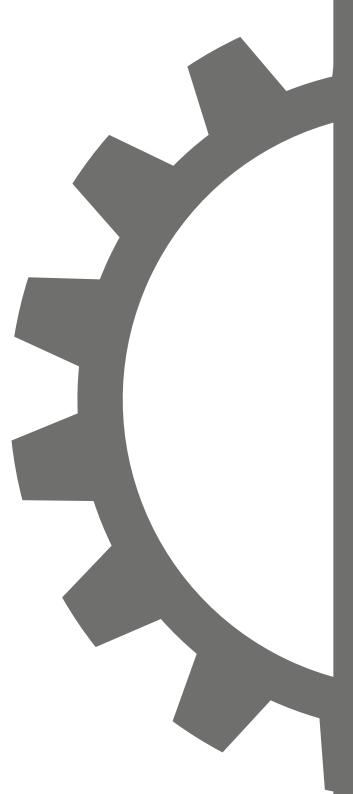


"Now comes the second machine age. Computers and other digital advances are doing for mental power—the ability to use our brains to understand and shape our environments—what the steam engine and its descendants did for muscle power. They're allowing us to blow past previous limitations and taking us into new territory. How exactly this transition will play out remains unknown, but whether or not the new machine age bends the curve of human development as dramatically as the steam engine, it is a very big deal indeed"

Erik Brynjolfsson and Andrew McAffe, The Second Machine Age

"Digital is the main reason just over half of the companies on the Fortune 500 have disappeared since the year 2000."

Pierre Nanterme, CEO of Accenture



#### **Carlos Silva Filho**

ISWA Vice President

The answers from the survey show that the industry is aware of the ongoing changes, that will lead to a convergence of digital technologies with the physical processes currently in use. This is because the processes identified as having the most impact seem to be those that combine traditional equipment with digital processes that may be able to take automated decisions and cooperate with each other and with humans.

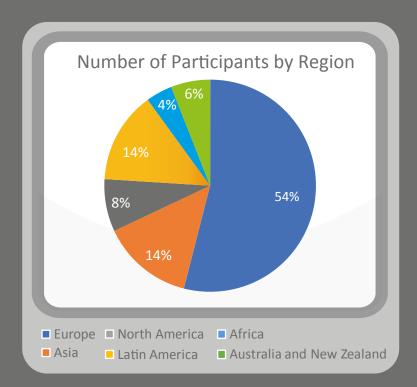
Another point, considering that the responses come from all parts of the world, is the difference between the current and previous industrial revolutions. The previous three revolutions started in developed countries and arrived with considerable delay to the underdeveloped/developing countries. The current revolution is more democratic and uniform, happening almost in real time all over the planet, thanks to the internet and the advanced forms of communication and interaction between companies and people.

A final conclusion can be taken from the interpretation of the answers given: those who continue to insist on the traditional model, will not be in the market beyond the next 15 years.

## The identity of the survey

The on-line survey was implemented from November 2016 to June 2017.

The target was to have at least 1000 completed questionnaires – finally there are 1087 participants from 97 countries. The geographical distribution of the participant is shown below.

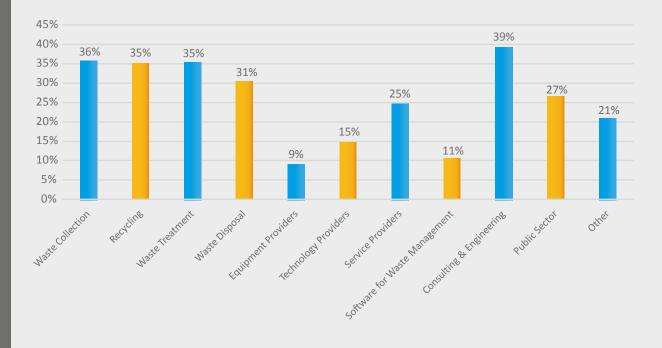


73% of the participants come from the private sector and 27% from the public sector.

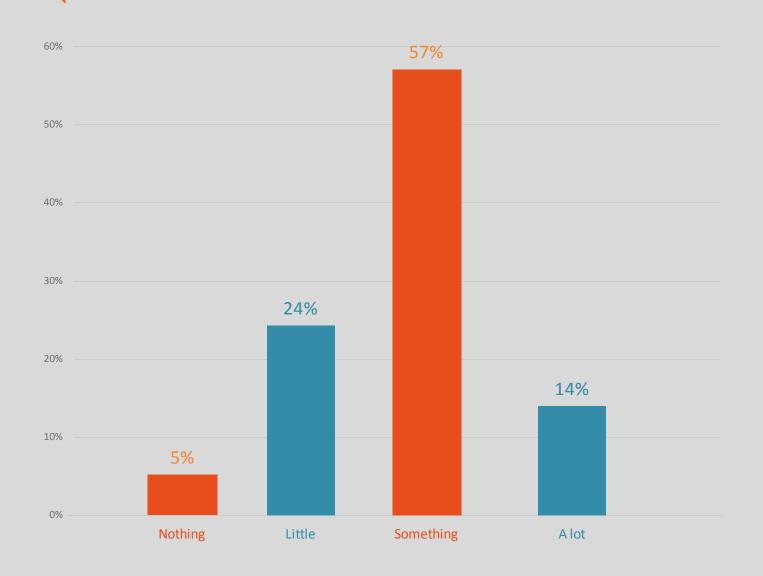
44% of the participants are Executive Officers or Board members and 56% non-executives.

The professional activities in which the participants are involved are shown below – notice that the sum of the responses is not 100% as many of the participants work in companies that cover more than one of those activities.

Q.5 Scope/Business Area of your Company/Organisation (please tick all that apply) Response Percent



## Q.7 How much do you know about the 4th industrial revolution?







### **Atilio Savino**

Only 14% of the participants consider that they know

a lot about the 4th Industrial Revolution, while 57%

consider that they know "something" and 29%

consider that they know "little" or "nothing". It seems

that the waste management industry is not so much

aware of the content of the 4th Industrial Revolution

and further information is required.

ISWA Board member representing the Regional Development Network of Latin American

Today as it was at the beginning of the XIX century, the inhabitants of this small and resource scarce planet, are witness of the dawn of a new era.

The 4th Industrial Revolution and what it means in terms of a new economy, the circular one, demands a society oriented in the creation of resources instead of generating waste.

Albert Einstein told us that we must think in a different way if we would like to change the status quo.

The solid waste sector could be fundamental in paving the way of the transition to the new economy

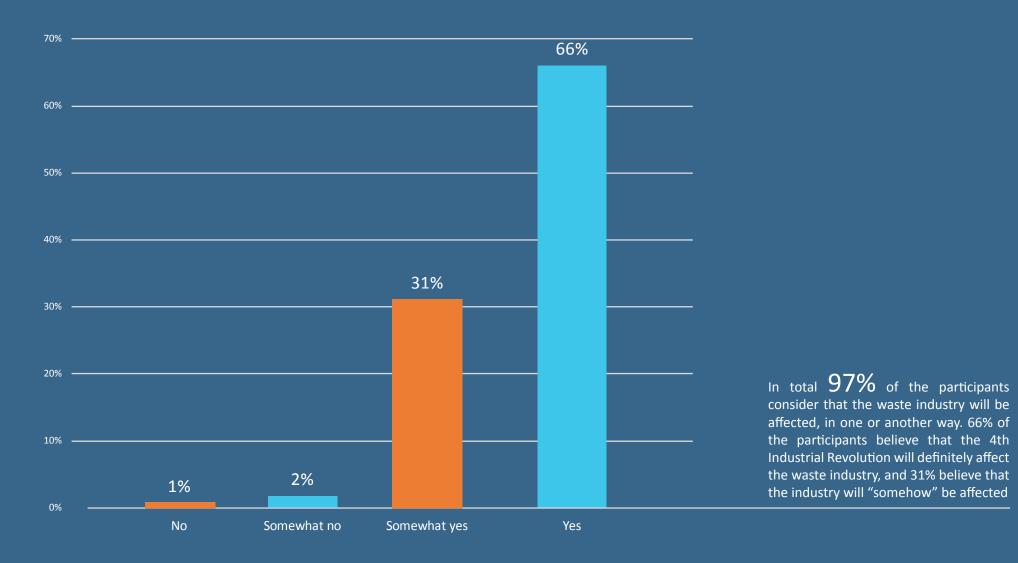
Waste should be redefined and the products should be designed to be part of the industrial metabolism that will copy the biological metabolism of nature.

Of course as Schumpeter taught us, about the destructive and creative ingredients of the essence of the capitalism, there will be winners and losers

Then the obligation is to understand our role in this spiral way to create a better world.



# Do you think that the 4th industrial revolution will affect the waste & recycling industry?



#### Prof. Karl Vrancken

University of Antwerp (Dept. Bio-engineering)

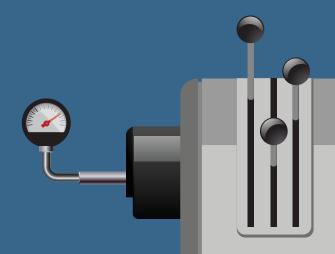
Digitalisation, robotisation and data sciences are strong technological drivers for change. The waste sector is clearly aware of the changes ahead of them. The introduction of sensors and robots is expected to revolutionise waste sorting and recycling. In order to drive and allow this impact, development and investment in big data and artificial intelligence is necessary. This is not yet in the comfort zone of the waste sector.

These new technologies will also be an enabler for the circular economy, the economic system where products will be shared, remanufactured or changed into a service. Embracing digital technologies will allow the waste sector to redefine their business in this new system.

#### Marco Ricci

Chair of the Working Group on Biological Treatment of Waste

- The topic of the 4th industrial revolution needs to become a topic in everyday business discussion and development of the waste & recycling industry, since only 14% declare to be familiar with it, but almost all interviewed (95%) expect that it will affect the waste management sector and 50% expect major impacts;
- The waste management sector will be affected by the existence of new materials but also by the enlarging interconnection of devices and products (the so called "internet of things"); impacts may represent a threat for the sector, but also an opportunity to enhance efficiency and conceive better and new ways for collection and recycling;
- The 4th Industrial Revolution will stimulate, at least somehow, circular economy, but the panel of answers can be broadly split into sceptics (i.e. 18% no) and optimists (i.e. 25% yes); the majority interviewed have limited expectation, probably reflecting the fact that the solid waste management sector and especially the MSW management branch is a rather traditional thinking one, bound to tenders with local authorities and to medium/long term infrastructural investments, so not keen nor rapid in innovations and disruptive changes.

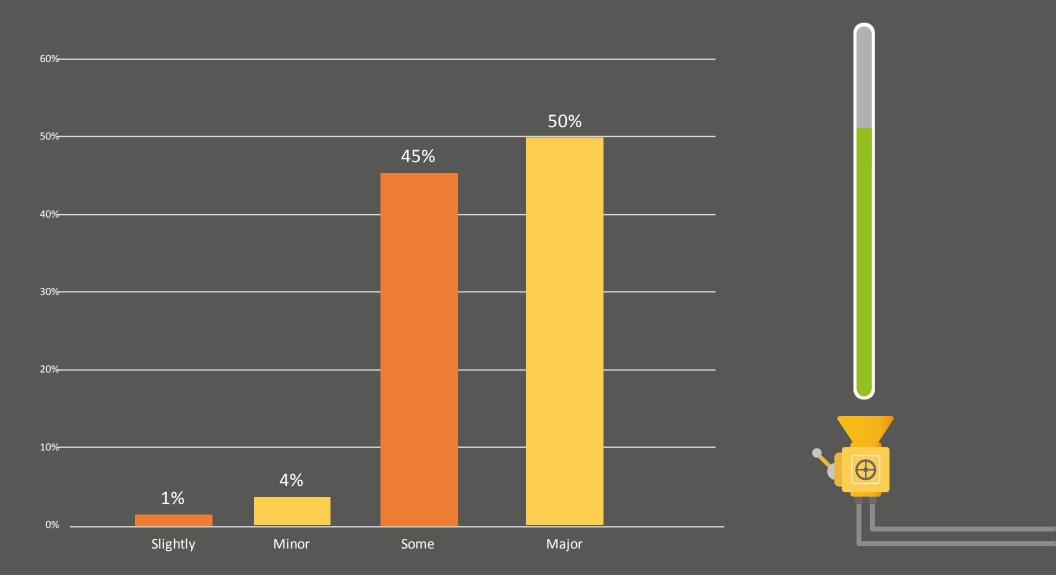






Q.9

If your answer in question 8 is "yes" or "somewhat yes", please specify the impact until 2030.





aware of the changes ahead, they do feel that the 4th Industrial Revolution will

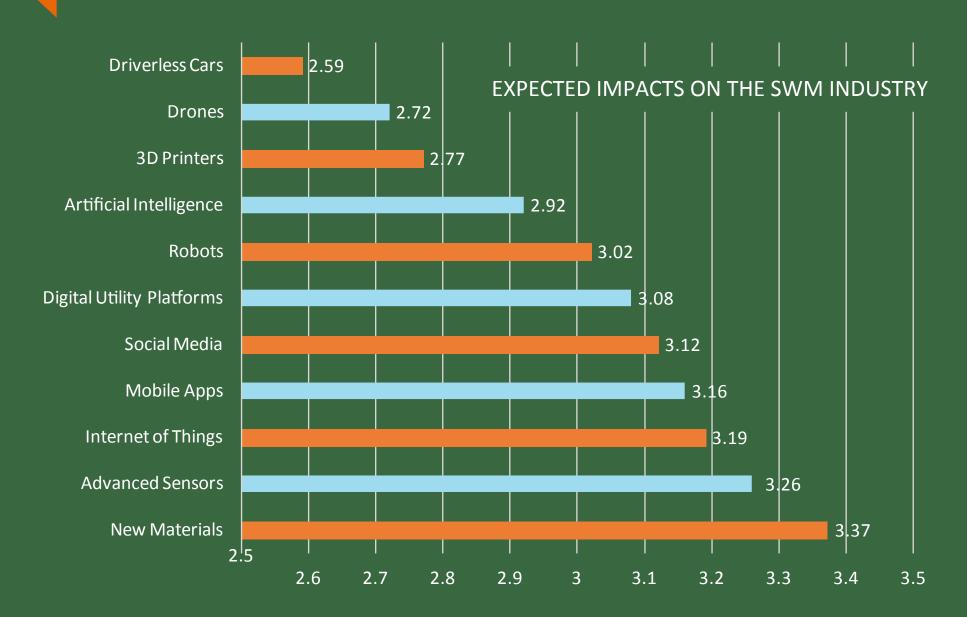
seriously impact the waste industry.

#### **Fernando Leite**

Vice President of ISWA's National Member in Portugal, APESB

Collecting data from waste will give us an insight of what consumers (industry and citizens) truly wants and what they use. By the analysis of the waste flow, not just in quantities, rates, deposition times or collection prediction but also in quality we'll be able to determine what resources will be needed for the "human ecosystem". This data collection will also provide a pool of information to consolidate the implementation of circular economy where resources will play a "currency role". But to fully conceive a circular economy and to collect the data we need to operate it the "man force" must be efficient, reliable and durable thus the need of technology in the form of robotic waste bins or robotic waste collection and treatment.





New materials, advanced sensors, and the Internet of Things are expected to have the most important impact to the waste management industry. Surprisingly, although robots are already in use in the waste industry, their expected impact is considered rather low, while the expected impact by driverless cars is considered the least out of the eleven categories. Another surprising fact is that participants expect a lot of impacts from social media and mobile applications, most possibly about waste prevention, reuse and recycling activities.



ISWA STC Chair

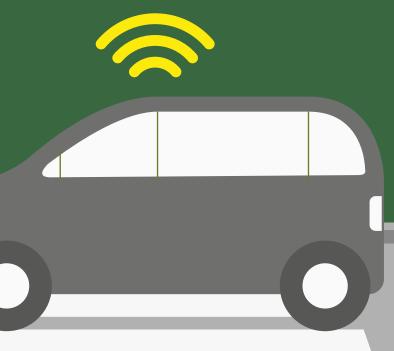
It seems interesting that the expected impact on the SMW sector is found relative high for all elements, I would have expected one coming out as a clear winner. Impacts from robots in SWM scored relative low compared to for instance social media, at the same time robotics were outstanding in innovation in 2030. I am surprised that mobile apps and social media scored so high in area for investment. I do not believe the waste industry will be ready for the transformation if the industry is not willing to invest more in robotics. Generally, I don't believe the waste industry I ready for the 4th industrial revolution!

### Dr.Eng. Alexei Atudorei

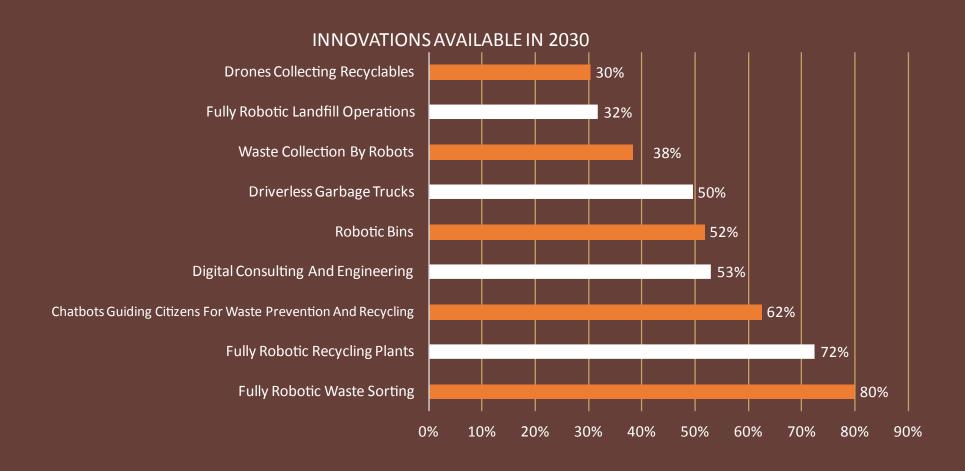
ISWA Board Member, International Waste Manager, Romania

The result of the survey shows the direct connection between the 4th IR, Circular Economy and the future of SWM.

In order to reach the targets for waste management in 2030, activities as innovations on fully robotic sorting and recycling plants (Q11), reuse and redesign of products and recycling (Q13), ecodesign and circular economy for plastics (Q15) are considered by those who responded at the survey as impacts with highest importance and the investments in the future will be on mobile apps, new sensors, social media, big data and new materials.



# Q.11 Please check the innovations that will be available in 2030. Response Percent



More than 60% expect that by 2030 chatbots guiding citizens for waste prevention & recycling, fully robotic recycling plants, and fully robotic waste sorting will be a reality.

In addition, more than 50% of the participants believe that in 2030 driverless garbage trucks, robotic bins, and digital consulting & engineering will be available.

Fully robotic waste sorting seems to be expected by 80% of the participants, something which is in accordance with the emergence of recycling robots that are already available.

72% of the participants expect fully robotic recycling plants, without any human intervention. This means that they expect that automation will cover all the plant's activities and not only waste sorting.

Surprisingly, chatbots are ranked third on the expected innovations.

It seems that the participants consider that a radical technological shift is on its way. According the responses to Q.10, the future of waste management will be robotic, guided by chatbots and somehow driverless!



### **Toralf Igesund**

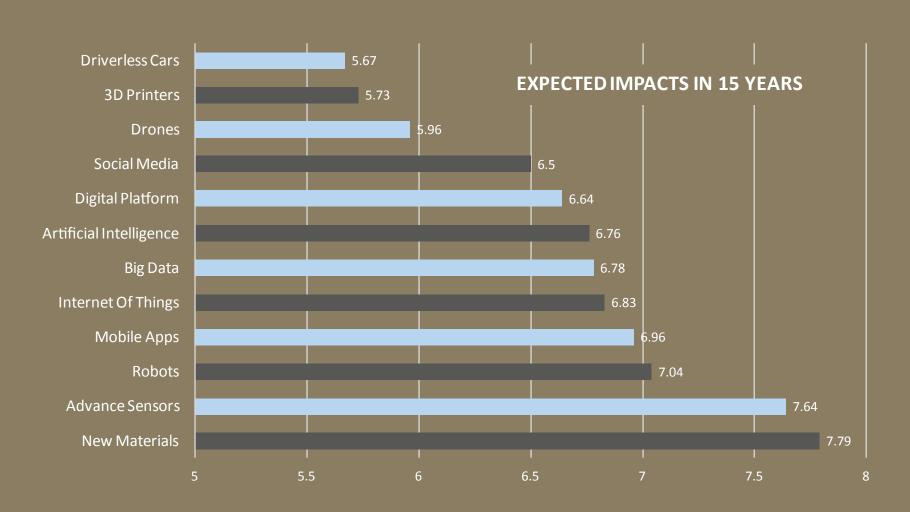
Head of Planning at BIR AS, Norway

I think the survey is very interesting, and it shows that people in the waste management community are aware that this is coming. But I believe that many people seem to underestimate how fast it will happen. I also believe that new materials will spread out with all sorts of products, and will create new problems for the industry in any case. All the innovations mentioned in Question 11 will be available by 2030. But even if they are available, many countries will not invest in it, but continue with manual labour. Most of the advances of Question 15 won't be difficult with the support of modern technology, but we still lack the standards and legislation that should be there first.



Q.12

Please rank the following developments in order of their impact on waste management & and recycling in the coming 15 years. Rank 1-12 (1= lowest impact; 12= highest importance) Rating Average (Out of 12)



#### Prof. Dr.-Ing. Rüdiger Siechau

CEO of Stadtreinigung Hamburg, ISWA National Member Representative

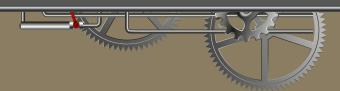
Overall the topics Industry 4.0 and digitalisation are ubiquitous and affect many fields in the waste management sector. The connection of devices and moreover the interconnection of processes enable the utilization of collected data and enhance communication processes. Especially big data and sensor techniques can be used for waste collection systems according to traffic situations and filling level of waste containers. Waste collection on demand may be a topic in future, particularly in big cities and wide areas. Consumer-friendly services and customer-focused solutions will be necessary in the waste management sector as well as cooperation of all involved parties for a successful and sustainable circular economy.

#### **Gunilla Carlsson**

Communications Director, Sysav, Sweden, ISWA Board

It's clear that change is here to stay! Waste management will deal with highly complex materials in the future and rely less on humans to treat the waste, shows the survey. Will this also mean that the quality of the materials will diminish? That people must find other employment possibilities - or will the waste sector provide even more jobs in the future?



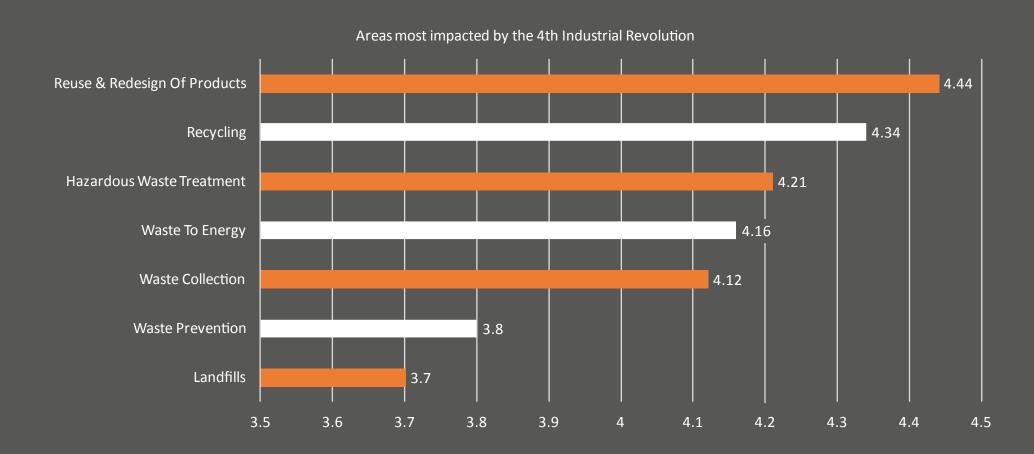


The participants were asked to rank the impacts of 12 specific developments on the waste management industry from 1-12 (12 for the highest impact). It is important to notice that average of all the 12 developments is 6.69, which confirms that the participants do expect a serious technological shift.

The answers show a consistency with the answers in previous questions ranking on top, with 7.79 the impacts of new materials, 7.64 the impacts of advanced sensors and 7.04 the impacts of robots. Big data, Internet of Things and Artificial Intelligence are in the middle of the ranking. At the bottom of the ranking are the driverless cars, the 3D printers, and the drones.

## Q.13

# Which of the following areas will be impacted the most by the 4th industrial revolution? Rating Average out of 7 (7 = most impacted)

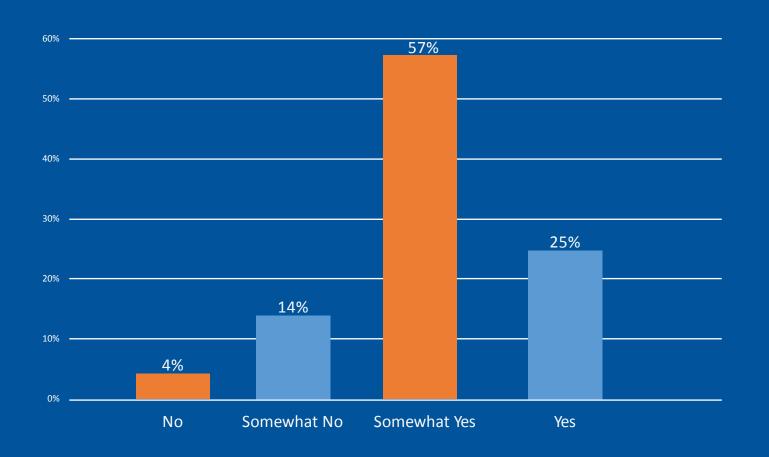


There is a clear consensus Reuse - Redesign of products, Recycling and Hazardous Waste Treatment will be the areas most impacted, followed by Waste to Energy and Waste Collection. Interestingly, the participants do not see waste prevention practices and landfills affected by the fourth industrial revolution. However, it must be noticed that driverless waste collection, when it will be commercialized, will probably be the more disruptive technology since it will redefine the dominant waste collection business models.



## Q.14

# Do you think that the 4th industrial revolution will make circular economy a reality for most of consumer goods?



82% of the participants expect that the 4th Industrial Revolution will stimulate, at least somehow, consumer goods, and 18% are rather pessimistic about it. Just one fourth of the participants are really optimistic and expects serious circular progress economy. It seems that the linkages between the 4th Industrial Revolution and Circular Economy as well as the potential benefits and further studied detailed.

### **Prof. Agamuthu Pariatamby**

Editor in Chief of Waste Management & Research.

4th Industrial Revolution (IR) is inevitable and its impact on waste management is eminent. The Revolution involves fusion of the digital technologies and waste management will see developments in each sector of waste management from robotics to sensors. The progress in IR is unprecedented and it will give the power to communicate, access to waste knowledge, 3-D printing of designs among others. The impact of IR on waste industry is major and most changes are expected in materials used in waste management. It is already evident that Robots will play a major role in 3R which will affect the circular economy of plastics, especially. Lastly, will the IR replace human labor and cause unemployment?

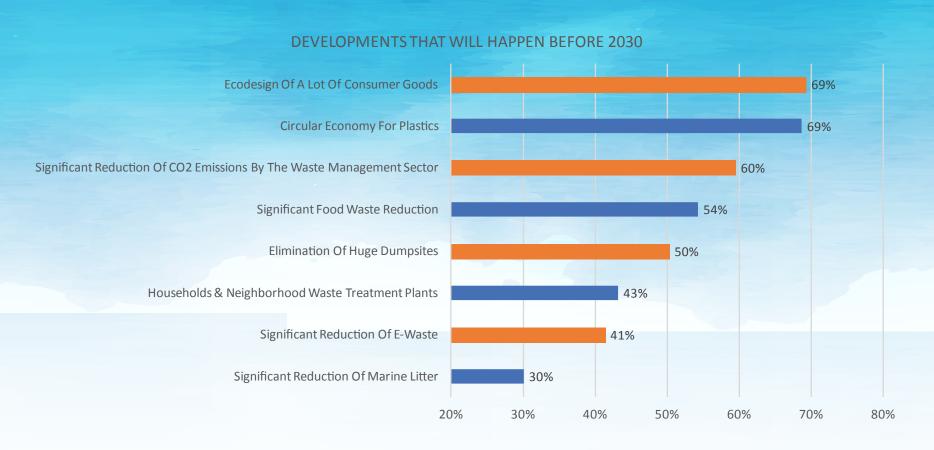
#### **Dave Ross**

Waste Management and Research Associate Editor

It's surprising that even a few respondents in the private sector expect that the 4th Industrial Revolution will have little or no impact on the waste management industry. Because so much of our industry has already begun to change significantly due to even relatively minor applications of advanced information and other 4th IR technologies. Given the major impact of social media on many facets of 21stCentury life, I would expect more waste management professionals to be looking for ways to harness this tool to enlist waste generators (essentially everyone with a pulse) as allies in the upstream efforts to reduce and recycle waste, so the downstream processes become even more efficient and effective.

Q.15

# Please check the areas of development that will happen before 2030 as a consequence of the 4th industrial revolution. Response Percent



69% of the participants believe that ecodesign of consumer goods and Circular Economy for plastics will be realized before 2030, in consistence with the replies in Q.13 and Q.14. 60% of the participants expect a further significant reduction of the carbon dioxide emissions, while 30% of them expect a significant reduction of marine litter and 41% a significant reduction of e-waste. Interestingly 50% of the respondents expect the elimination of huge dumpsites.





#### Joachim Quoden

EXPRA Managing Director, Chair of ISWA's Working Group on Governance and Legal Issues

Industry 4.0, reinforced with new waste legislation and enforcement, will further enhance the efficiency of municipal waste treatment. Already today data analysis tools improve key waste management services. Plus, digital tools in the future will render sorting at home much simpler than today. For instance, applications helping to identify the exact bin for the right packaging. This is important as the better the waste is sorted, the better it is recycled, the less ends up in landfills. Additionally, the sorting equipment which is already today able to sort automatically will be further improved so that more different waste streams can be sorted in an almost pure quality. Consequently, thanks to technological development we will increase drastically plastics' circularity, reduce strongly littering and avoid marine litter.

### **Derek Greedy**

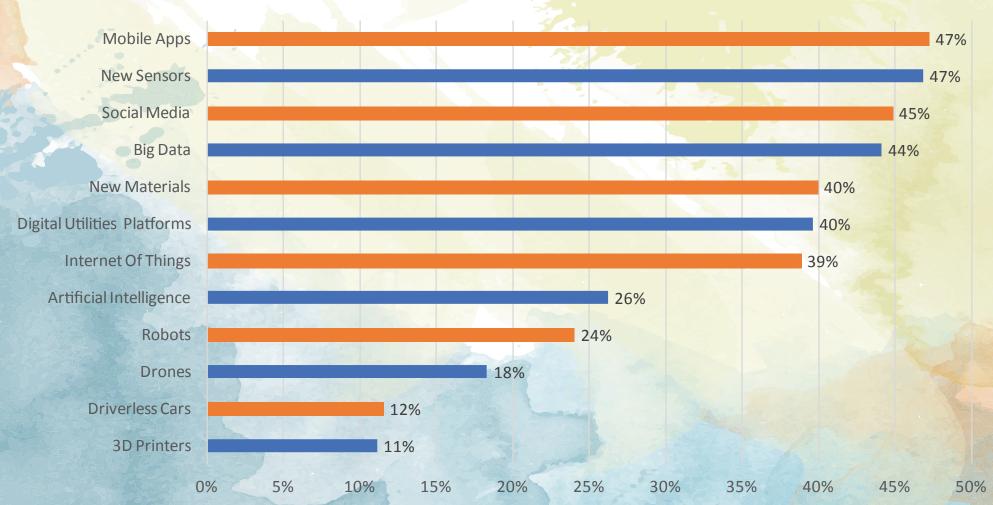
CIWM, ISWA Board of Directors

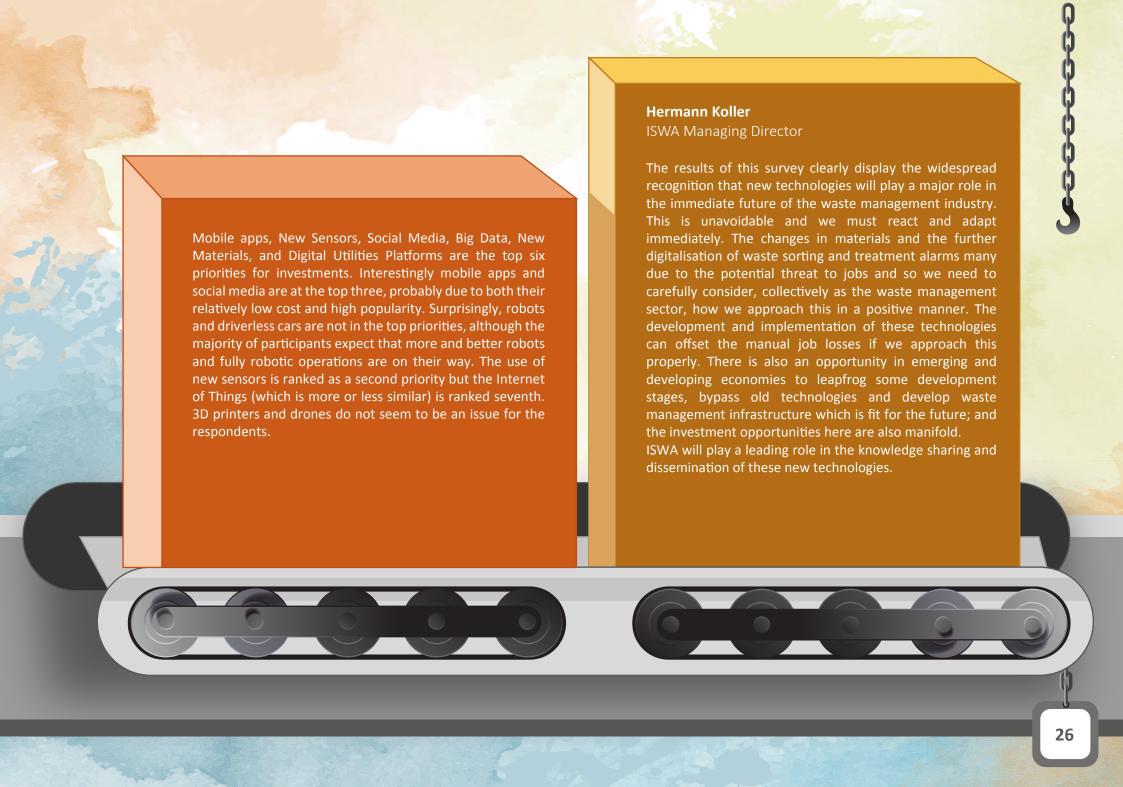
It is not a surprise to me that so few people are aware of the 4th Industrial Revolution as many will not have been aware that there was a 2nd let alone a 3rd. However, despite this the sustainable waste management industry clearly will need to adjust to a new era of technological advancement. Perhaps, as the survey shows, the early wins will be in reuse and design. Improved information technology will, without doubt, lead to better data which in turn can be used to improve efficiency through technological advancement.



# Q.16 Please check the areas where you think your organization should invest. Response Percent







## Instead of conclusions

During the 8 months of the implementation of this survey, there were some interesting developments related to the fourth industrial revolution:



• One more commercial robot for sorting recyclables from mixed waste stream was presented.



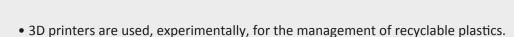
• The first wind – powered recycling robot has started its operations.



• The first driverless waste collection experiment was successfully demonstrated.



• The world's first mall for recycled and repaired goods has become mainstream.





• More than 1000 new patents for new composite materials have been submitted.



• The so-called Internet of Bins (the incorporation of advanced sensors in waste bins) is becoming more and more popular.

• Several platforms and mobile apps for recycling systems have been realised, including platforms for informal recyclers.





- The so-called Internet of Packaging is gradually considered a cornerstone of the shift towards a sustainable management of packaging recyclables.
- Several start-ups that deliver innovative solutions for plastic residual streams are on their way to deliver commercial solutions.



- Turning food waste to proteins that are used to feed animals has become fully commercialised.
- Chatbots dealing with waste management and recycling are already available.





### Gary Crawford, ISWA Board Member / Veolia, VP - International Affairs

The survey is very enlightening and provides a snapshot of the waste & resource management (W&RM) sector's views on the emergence of the fourth industrial revolution (4th IR). I expected that greater than 50% of the respondents would consider that the 4th IR would have a major impact on the sector by 2030 (Q9).

We already see real enthusiasm on the "smart city market". Cities and businesses are recognizing that the rise of the digital technology and innovation offer new opportunities to increase their: efficiency and performance, quality of life, and ability to integrate stakeholders.

Accelerating the use of digital technology and robotics requires new co-construction partnerships and new business models. The W&RM sector will need to move beyond its traditional activities and seek complimentary expertise combined with its own know-how that will open-up new opportunities.

It will also be necessary to be more inclusive: facilitating access to information, integrating local economic actors and citizen partnerships.

W&RM companies have developed smart solutions capable of improving waste flow control and empowering citizens and businesses to recover more and reduce the problems it creates. The use of sensors and robotics is already being implemented and will continue to have a significant impact on waste collection, sorting and recycling performance as well as the transition towards a circular economy.



The 4th Industrial Revolution not only is present, but it seems it's going faster and faster. It is obvious that we are living in a great transit period in which new digital technologies will initially stimulate the digitisation of the current business models and then, they will transform them radically as they have already done with other industrial sectors like the media sector, the tourism sector, the car industry etc. In this rapidly changing landscape, disruption of traditional industries is becoming the new "business as usual". A recent report predicts that by 2020 one third of the top 20 firms, in every industry, will be seriously disrupted or even failed. Disruption will be the rule and not the exception for the next 10-15 years and the waste management sector will not escape from this fate.

The on-going industrial revolution represents a potential for substantial benefits in recycling and waste management, because with the new cheap and energy efficient sensors, many industries will have the possibility to follow closely all the life cycle of any item sold. This will allow product designers to optimize the design, minimize useless functions and materials, prevent damages, improve maintenance, and finally develop closed loops of clean materials. "Zero waste" approaches for specific supply chains will become more realistic than ever. Reuse, recycling and material recovery will become easier, from a technological point of view.

But the elimination of waste in certain parts of the supply chain will not necessarily create wasteless supply chains. Take the example of 3D printers. Any wasted material during the production of 3D printed products can be reused in the additive manufacturing process. So, this phase of the supply chain can be, in many cases, really wasteless! But, what is the raw material of additive manufacturing? A plastic powder (polyamides, thermoplastic elastomers, polyether ketone, polystyrene) is the most commonly used. So, how those plastics are prepared? Are the 3D printed products going to be recyclables? Is it better or worse to make production of plastic products much easier (and with the potential to be fully decentralized in each and every household)? And how about the recyclability of the 3D printers themselves?

It seems more logical that in most cases, the waste will be eliminated from parts of the supply chain, but it will be relocated, in new forms, in other parts of it. It is also obvious that the new solutions will create new questions, feeding with new fertilizer the evergreen tree of human knowledge and intelligence.

The exponential technologies have the potential to resolve many of the global challenges we face. But this is not possible to be done by the market mechanisms alone. Although the technological means are more than enough to create clean closed materials loops, they will never be realized on a massive scale if eco and modular design will not prevail the mass consumption markets. So, this enormous positive potential relies upon the adoption of the Extended Producer Responsibility principle by the major industries. As everyone understands, this will not come easily, soon and for free, unless there are strong, global and systematic policies as well as social demand for that change.

The 4th Industrial Revolution and the exponential technologies make this clearer than ever. It is not the technologies we miss, it is the right global – local cooperation and the proper governance patterns that are required in order to utilize the 4th Industrial Revolution potential for a shift to sustainability. We can't manage exponential technologies with a slow linear evolution of the current governance models. The case is still open, we still can hope for a better future, under the condition that a new paradigm of global – local cooperation and governance will be adopted.



"Technology is not an exogenous force over which we have no control. We are not constrained by a binary choice between "accept and live with it" and "reject and live without it". Instead, take dramatic technological change as an invitation to reflect about who we are and how we see the world. The more we think about how to harness the technology revolution, the more we will examine ourselves and the underlying social models that these technologies embody and enable, and the more we will have an opportunity to shape the revolution in a manner that improves the state of the world."

Klaus Schwab, The Fourth Industrial Revolution

"You cannot wait until a louse burns down to buy fire insurance on it. We cannot wait until there are massive dislocations in our society to prepare for the Fourth Industrial Revolution."

Robert J. Shiller, 2013 Nobel laureate in economics

