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The Industry 4.0 and the ecological defence of the environment

Industry 4.0 a ekologiczna ochrona środowiska

ABSTRACT

The following paper presents in an overview some areas of the very large range of capturing of the Industry 4.0, that have undoubtedly a potential to contribute to the defence of the environment and its sustainability. Even, if the 4th Industrial Revolution, in the form of the Industry 4.0, had not been mainly created cause of ecological aims, there can be defined a few aspects, which 8 help in terms of protecting the environment, minimizing waste, transportation costs, or resources consumed and simultaneously on the other hand not losing the entrepreneurs' competitiveness for companies.

The 4th Industrial Revolution is characterized by its new technologies, i.e. big data or the cloud and an overall centralized mindset on digitalization. Nevertheless, in this particular paper is highlighted the ecological and sustainable part of the concept of the Industry 4 is highlighted, although naturally all aspects of it cannot be discussed completely in this written work.

Keywords: Industry 4.0, ecology, sustainability, big data, CPS

STRESZCZENIE

Poniższy artykuł prezentuje przegląd niektórych obszarów z zakresu Industry 4.0, które mają potencjał, aby znacząco wpływać na ochronę środowiska i jego zrównoważenie. Nawet jeśli powodem powstania tzw. czwartej rewolucji przemysłowej w formie Industry 4.0 nie były pobudki ekologiczne, można w niej zidentyfikować pewne aspekty, które mogą pomóc w ochronie otaczającego nas środowiska, minimalizacji ilości odpadów, kosztów transportu czy zużytych surowców, a jednocześnie nie tracić siły gospodarczej i przedsiębiorczości firm. Czwartą rewolucję przemysłową z klasycznego punktu widzenia charakteryzują nowe technologie, jak big data, chmura, oraz ogólne nastawienie na cyfryzację. Pomimo jej silnego ukierunkowania na nowe technologie, w niniejszym artykule wyszczególniono głównie aspekty ekologiczne i zrównoważenie koncepcji Industry 4.0. Oczywiście, ze względu na ograniczoną objętość artykułu wszystkie kwestie nie mogły zostać naświetlone w sposób wyczerpujący.

Słowa kluczowe: Industry 4.0, ekologia, zrównoważenie, big data, CPS.

1. MOTIVATION

The requirements to stop climate warming effects all over the globe, well-known climate warming effect are huge. According to the Paris Agreement (on Climate Change) to stop this negative trend, it is said, the 1,5 degrees Celsius goal must be reached. At least there is the will from more than 110 countries world wide to get finally there by 2050. In Europe, the European Union is determined to be the first carbon-neutral continent. I.e. China wants to reach it at least by 2060 (United Nations, 2020). The roadmap for achieving this undoubtedly ambitious target is not easy to navigate.

In 2019, and probably 2020 the overall emission of so-called greenhouse gases from fossil fuels all over the world unexpectedly meaningfully decreased, which was not an effect of changes in the mindset of the entrepreneurs and awareness of sustainability and ecological importance. The cause of it was just the spreading out of the virus COVID-19 since 2019, causing a pandemic and world wide lockdowns. According to the latest estimation of the Global Carbon Project (GCP) for 2020, it shows an expectation of an overall amount of 34 Gt (billions of tones) of CO_2, which would mean a fall of 2,4 Gt in

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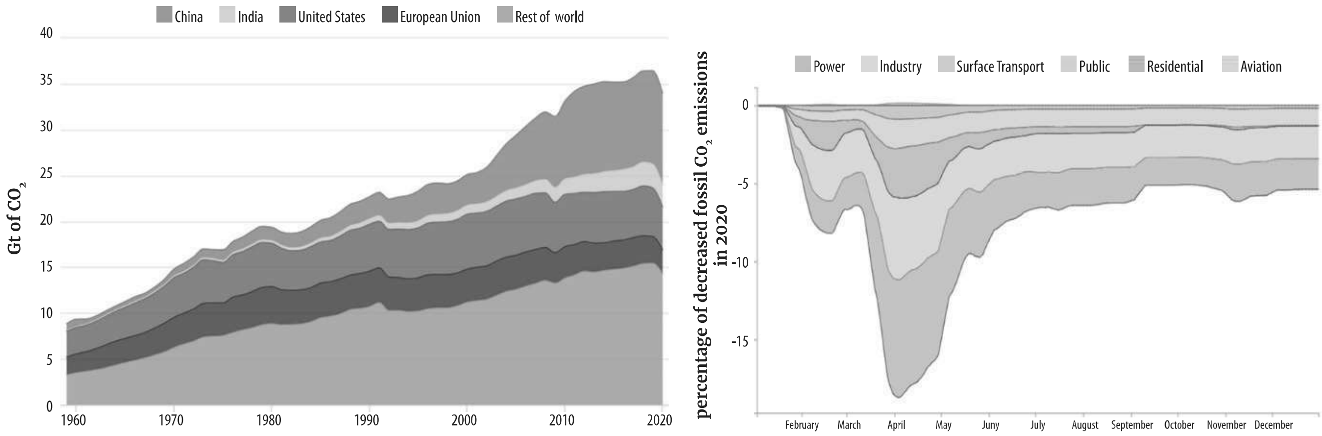

Figure 1: Fossil emissions in Gt for main pollutants (left); drop of fossil emissions during pandemic year 2020 (right)
Soure: Carbon Brief, 2020

comparison to 2019 (Carbon Brief, 2020). It was a tremendous drop in the whole history of greenhouse gas emissions (Figure 1) since the beginning of monitoring, probably only compared with the period of time during the 2nd World War.

According to Figure 1 (here: on the left) the "big 4" polluting countries in the world of the fossil fuels puts China in 1st place, which emits much more than the others. The 2nd most polluting country is the United States, then India and finally the European Union, containing almost all European countries. In comparison to 2019, in 2020 emissions decreased in the case of China 1,7%, in USA 12%, in EU 11%, in India 9%.

On the right-hand side of figure 1 is shown the percentage of decreased fossil emissions during actual pandemic of COVID-19 in 2020 is shown. Thus, the greatest drop of emitted fossil fuels was observed in the month of April, where in many countries coronavirus had already spread out and the lockdowns had already been put in place. Till now almost the whole of industry is suffering from the impact of the pandemic.

On the way to minimize knowingly the emissions of greenhouse gases under the defined limits, set by the Paris Agreement (from 2015) in the long-term and not only because of the extraordinary circumstances like the still ongoing pandemic, it is a sustainable method of approach that is needed. One of the very promising solutions can be seen in the well-known (not only within scienctists' circles) Industry 4.0, which is the more physical embodiment of the superior, abstract term – the 4th Industrial Revolution. Although this concept in meaning does not aim at a core understanding of the topic of sustainability, it is worth analyzing it in order to understand its contribution towards decreasing emissions of CO_2 and 36 ecologically responsible handling of the resources we use.

Industry 4.0 is a relatively new concept and requires a new mindset in the way of leading companies and is not only limited to one's own factory but has influence also on the whole chain of added value; from the suppliers till the final customers.

For now, almost every implementation of new concepts has been caused by improving economic indicators. Surely, Industry 4.0 offers a new milestone of cheaper and more lean-oriented production, which could be the next step on the optimization path, where particularly the classic and well-known lean tools seemed to reach their mighty potential a long time ago. Beside the obvious, economic advantages of Industry 4.0, this concept can also prove its right to exist through its contribution to resource saving and therefore may be important on the way to an awareness of the negative results of non-sustainable, ecological acting.

In terms of Industry 4.0, which urgently was created in Europe, if it can show meaningful advantages on the economic side, it could be an interesting concept especially for the "big 3" of the most polluting countries in terms of CO_2. In this case Europe can play a pioneer role according to the successful implementation of Industry 4.0 into companies. If companies from China, the USA or India finally realize the whole range of the potential and advantages, also on ecological side, this may positively affect the future development of the environment. Industrialization especially in these particular countries is going to have the greatest positive effect on decreasing emissions of greenhouse gases, more than any efforts made by the European Union. But of course, even from the perspective of the economic advantages of Industry 4.0 – this concept is worth implementing by every country in the world, no matter how big or small the company may be. The resistance against this relatively new concept may lead to unprofitable acting and in worst case may end in a company disappearing from the trade market.

Industry 4.0 can be seen as a example of protecting the environment and at the same time acting still being enterprising in a profit zone. Therefore, there is no longer a dilemma between economic and ecological behaviour. Industry 4.0 is a concept where its impact goes far beyond the economic sphere, influencing not only the occupational part of life but also our private lives.

2. THE TIME-RELATED FRAMING OF THE CONCEPT OF INDUSTRY 4.0

In scientific literature, up to the present, four industrial revolutions exist. They can be taken as the most important milestones in technological development over time, without which the advances of the present day would not be possible.

The Figure 2 shows the development of the individual and specific Industrial Revolutions according to a time axis.

According to the figure 2, technological development can be divided till now into four Industrial Revolutions overall, where the start is declared to be during the 2nd half of the 18th Century (1784); although the exact year is not clearly defined in the literature sources and can vary from 1775 till 1784. Each of them has its own, main characteristics, which distinguish it from the others. Thus, the 1st Industrial Revolution is often described as mechanization, the 2nd electrification, the 3rd automation and finally the 4th as digitization, where we are currently situated.

In the following, the four Industrial Revolutions will be presented more deeply.

The start of the 1st Industrial Revolution, is often estimated in some scientific sources as the year 1775 (Yokogawa, 2019; Saurabh, Prashant, & Santosh, 2018, p. 234; Dalenogare, Benitez, Ayala, & Frank, 2018, p. 384), which at first took place in England (Ślusarczyk, 2018, p. 235). The most important technological inventions of those days undoubtedly include steam and water power (Ghobakhloo, 2018, p. 2; Ślusarczyk, 2018, p. 235). Water power, that is the energy coming from water, was in use even shortly before the beginning of the 1st Industrial Revolution and was at that time mainly implemented in mills (Rutkowska, Michalski, Sulich, & Rothe, 2017, p. 4), which were, in other words, driven by a renewable energy source – such an important topic from today's point of view. In the case of steam power, which was invented by James Watt (one of the most significant scientists for this period of time), was mainly implemented in steam machines from 1769. Especially steam machines can be seen as the most important driver for the increasing of mechanization in this specific period of time. In the following years of the 1st Industrial Revolution took place an optimization of steam machines took place, which finally resulted mainly in the improving of the degree of efficiency of this source of energy (Kagermann et al., 2013, p. 17). But the improvement was not only limited to steam machines. Another industrial area, which was in those days in focus, was the textile sector (Rojko, 2017, p. 79), but also the mining industry (Schwarzbach, 2016, p. 12), which played then a crucial role, as one of the most important branches of industry. Therefore, it is unlikely to be a coincidence, why in many figures, where all the 4 Industrial Revolutions are presented, is very often figured a picture of a mechanical loom is often shown (Australian Government, 2017, p. 6), as the symbol of mechanization – the characteristic of the 1st Industrial Revolution, as earlier above already mentioned.

The 1st Industrial Revolution (presented above) lasted a relatively long period of time; until the year 1850. It can be summarized as the greatest technological and in terms of productivity biggest push, where all the time before almost

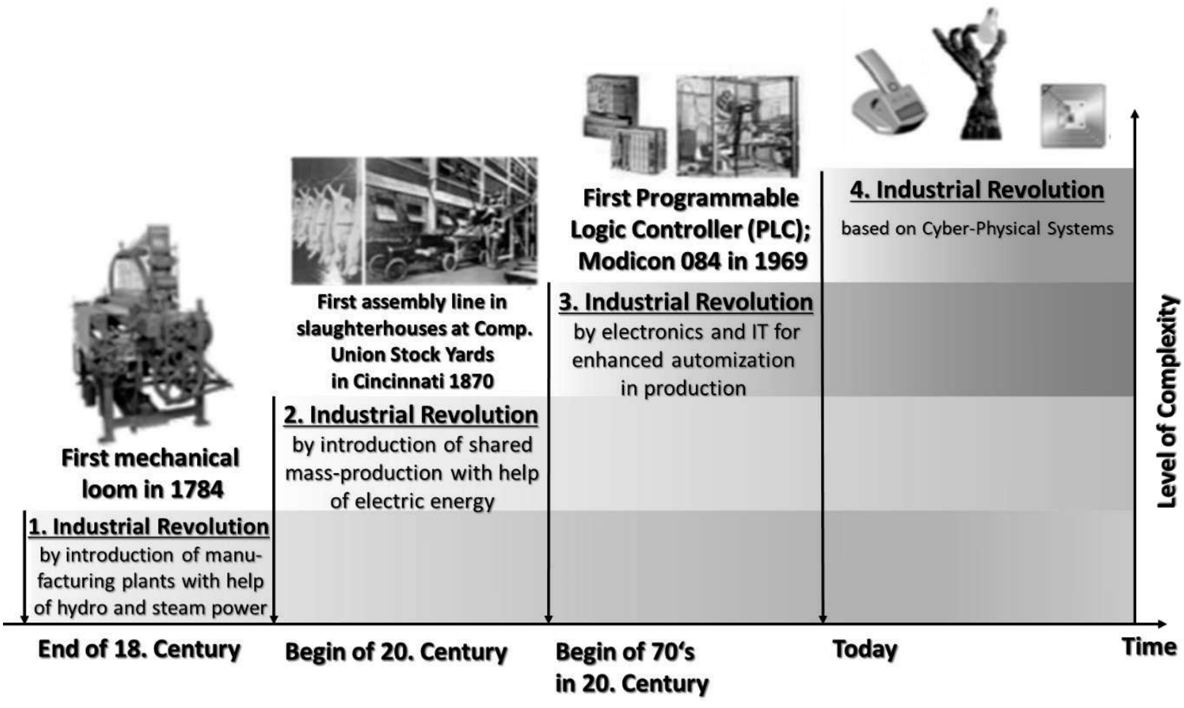

Figure 2: The four stages of the Industrial Revolutions
Soure: based on Kagermann, Wahlster, & Helbig, 2012, p. 13; Anderl, 2014, p. 2

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everything had to be done by hand and the limited human muscular strength, or (in the best case) with the help of some animals as livestock.

With the second half of the 19th century began the 2nd Industrial Revolution, where (again) the starting year is not clearly defined (i.e. as 1870 in (Saurabhet al., 2018, p. 234), or 1840 in (Dalenogare et al., 2018, p. 384)), it is mainly characterized as electrification (Hermann, Pentek, & Otto , 2015, p. 5). At this particular period of time (as opposed to the 1st Industrial Revolution), it took place not only in Europe but also in the United States (Ślusarczyk, 2018, p. 235). In those days an inventor, called Thomas Alva Edison constructed the dynamo, which was then put to use from now on as a machine, having the ability to generate electric current. Especially because of this invention the entrepreneurs were now able to install their facilities on the shop floor at any place they wanted, being fully free in the design and layout of the structure of production. The second, but not least important invention of the 2nd Industrial Revolution was the creation of assembly lines, which is dated at 1870 (Australian Government, 2017, p. 6) in factories of several branches of industry (Kagermann et al., 2013, p. 17). As examples of its use during the timeline of the 2nd Industrial Revolution can be seen the sector of the slaughterhouses (therefore see also Figure 2), or the automotive industry. In result, enterprises saw a real way finally to satisfy for the first time the upcoming rising demand of the customers (Ślusarczyk, 2018, p. 235). The pioneer in this technological area is the commonly acclaimed Henry Ford, the founder of the one of most famous car manufacturers – FORD. It was he, who through implementing the classic assembly lines within the shop floor and spread the popularity of it all over the world, which was (by the way) also the enabler of the creation of so-called mass production (Ghobakhloo, 2018, p. 2; Rojko, 2017, p. 79), and is well-known even until today. But implementing of assembly lines was not only limited to technological renewal. It also influenced the approach and point of view towards human work itself and improving its overall efficiency. With the start of mass production (mentioned above), the whole amount of work tasks could be divided into the number of work stations within a specific assembly line (Ślusarczyk, 2018, p. 235), also called as Taylorism (Schwarzbach, 2016, p. 13). Thus, the whole amount of work tasks within an assembly line did not have to be executed by one and the same operator, as before, who from now on did not have to know all the single manufacturing steps. From this period of time comes the well-known quote by Henry Ford concerning the very famous model "T" of Ford (which was produced only in one colour). In this quotation he shortly defined (probably unconsciously) the real core mindset of mass production. The citation goes as follows: "You can have any colour as long as it is black" (Rojko, 2017, p. 79).

As time went by, in this case the ongoing development in the electrical sphere could be seen. This circumstance was the beginning of the creation of the higher shape of electrification – the electronic components and the birth of the fully new scientific discipline called Information Technologies (IT). Continuously the properties of electronic and IT devices were improving in several ways, like the capacity of power, digital memory and its overall efficiency. On the basis of these new technologies, finally was then possible the realization of automation in several types of production machines (Kagermann et al., 2013, p. 17; Schneider, 2019, p.406). The development of electronics, automation (Rojko, 2017, p. 79), and the creation of so-called PLC's - Programmable Logic Control in 1969 (Anderl, 2014, p. 2), are the main characteristics of the 3rd Industrial Revolution, the next step towards improvement in the direction of efficiency and even quality of production (Australian Government, 2017, p. 6).

Officially, the 70's of the 20. century are assumed to be the beginning of the 3rd Industrial Revolution (Australian Government, 2017, p. 6), (also but seldom can be found the 60's (Rojko, 2017, p. 79)), in which by usage of automation many processes within industrial production were optimized (Ghobakhloo, 2018, p. 2; Hermann et al. , 2015, p. 5). Often this Revolution is also acknowledged as the unofficial start of digitization – the main characteristic of the present, meanwhile the 4th Industrial Revolution (Kagermann et al., 2013, p. 13). Because of the development till the advanced state (today) of its core areas, i.e. automation, communication and IT, the newest Revolution is no longer science fiction realize implementations in these spheres. The actual 4th Industrial Revolution, is often described using the very popular term - Industry 4.0. In its purest form Industry 4.0 uses so-called cyber-physical systems (CPS), which (by the way) represent the smallest units, to enable nearly complete integration and interaction of every facility in professional life, also including the human part or staff (Schwarzbach, 2016, p. 13) in daily work.

3. THE ORIGIN OF THE CONCEPT "INDUSTRY 4.0", ITS DEVELOPMENT AND DEFINITIONS

As the official start of the 4th Industrial Revolution, also so-called Industry 4.0 (another known terms are Industrie 4.0 or in short: I4.0 (Kagermann et al., 2013, p. 5–33)) is acknowledged the year 2011. In that particular year, at the yearly trade fair of Hanover (a city in North of Germany), the word – Industry 4.0, its concept had been used and presented publicly for the very first time (Qin, Liu & Grosvenor, 2016, p. 1; Kagermann et al., 2013; Küper-Rampp, 2019, p. 48), describing the newest shape of the Industrial Revolution in the 21th century as a source of potential for strengthening the competitiveness of German industry (Ślusarczyk, 2018, p. 233), focusing mainly on the key branches of industry, like automotive; very typical for Germany.

Basically, the German concept of Industry 4.0 was a governmently-driven programme (Rojko, 2017, p. 77-78), which was created by a collaboration of different representatives of the key industry sectors and also scholars' circle (Ślusarczyk, 2018, p. 233). The aim was to create a long-term strategy in a technological manner for Germany as a country till 2020, ensuring at the same time the competitive environment for its companies, often acting in a difficult world trade market. In general, the concept of Industry 4.0 was a part of an overall governmental agenda of innovation, named: "High-Tech Strategy 2020" (Kagermann et al., 2013, p. 17). It was a result of the huge interest in the new technologies and their importance (Pereira & Romero, 2017, p. 1207) now and in the future.

Shortly afterwords, Industry 4.0 came into focus not only in Germany, but also in many european countries and the entire European Union (Ghobakhloo, 2018, p. 2; Rojko, 2017, p. 80), where according to the Commission of the European Union it is known as "Factories of the Future" (FoF) (Filos, 2015, pp. 1-12).

How exactly the concept of Industry 4.0 is dealt with in different countries, is briefly presented in the following three paragraphs.

Similar to Germany, in most countries the start of the 4th Industrial Revolution often came from governmental circles (Rojko, 2017, p. 78). According to the appearance of the concept of Industry 4.0, not everywhere was this new Industrial Revolution known as Industry 4.0, like in Germany. Thus, in England is more popular the term: "Catapult" (O'Sullivan, Andreoni, López-Gómez, & Gregory, 2013, pp. 6-7), in France "Industry of the future" (NFI, 2015), or also "Industrie du Futur" (Klitou, Conrads, Rasmussen, Probst, & Pedersen, 2017), in Holland "Smart Industry" (Haverkort & Zimmermann, 2017), in Spain "Industria Conectada 4.0" (Buisán & Valdés, 2017), in Sweden "Produktion2030" (Produktion2030, 2020), in Italy "Fabbrica Intelligente" (Bettarini, Di Giacomo, & Tartaglione, 2016). In the case of Portugal (Aparício da Silva, 2018) i.e. it is common to use the German term – Industry 4.0.

In the USA the concept of Industry 4.0 came into focus one year later as in Germany, in 2012 (Rojko, 2017, p. 78). But similarly to Germany, in the end it was the output of a collaboration of different representatives of the American Industry companies, i.e. General Electric (Posada et al., 2015, p. 27; Ślusarczyk, 2018, p. 233), Fujitsu and IBM (Industrial Internet Consortium, 2019, p. 55). Finally, the terms like "Industrial Internet" and „digital supply network" (Aslanertik & Yardimci, 2019, p. 550) were born, where definitely the first one is much more popular. To be more exact, the full term describing the 4th Industrial Revolution in USA is named the "Industrial Internet of Things" (IIoT) (World Economic Forum, 2015, pp. 3-10). Compared to the German's Industry 4.0, the American's Industrial Internet of Things comprises greater sphere of the professional life. It containts i.e. also transportation, mining, so-called power engineering, or even public sector (Rojko, 2017, p. 78).

In China, the Industry 4.0 is known as "Made in China 2025" (Zhou, 2017, p. 3969; Wübbeke, Meissner, Zenglein, Ives, & Conrad, 2016), which was firstly initiated and created (similar to Germany and the USA) through the Chinese ministry of Industry and information technology by collaboration with the local academy of engineering in 2015 (The State Council. The People's Republic of China, 2020). The Chinese 4th Industrial Revolution is mainly oriented on the German equivalent. Additionally, the "Made in China 2025" comprises the ecological development and supporting creation of so-called green energy. The declared strategical aim of China is to take over the role of the industrial leader from countries like Germany or Japan by 2035 (The State Council. The People`s Republic of China, 2020). Thus, the scheduled path of Chinese industry for the next years and decades is clear; ending the reliance on low-budget items and instead putting the concentration on high quality products (Rojko, 2017, p. 78), accepting (on the other hand) also less volume production. It is an open question, what it will mean for the Chinese labour market.

Although there are some differences in the understanding of the 4th Industrial Revolution all over the world, at the core they often describing almost the same, new technologies as the main characteristic. Unfortunately, the 4th Industrial Revolution and particularly the term „Industry 4.0" is not clearly defined, which additionally can be the reason, why so many companies have their difficulties with general understanding of it and which hallmarks are contained (Aslanertik & Yardimci, 2019, p. 550).

In the next paragraphs are presented just a few definitions of a great amount of (possible to find) definitions of Industry 4.0.

For example, Aslanertik and Yardimci (2019, p. 550) Industry 4.0 describes a new (here: the 4th), this time a digitized transformation of technology. Thanks it, on a bright scale there can be used so-called smart, digital technologies, which in turn are crucial in terms of creating new technologies of production and also new business models, even yet unknown.

The essence of Industry 4.0 is to create a perfect, real reflection of real life (including all its parts) and transfer it into the digital world. The so-called CPS (cyber-physical systems) units make it possible, by building a basic part in the future, smart factories. The existence of CPS will enable further digitisation, where via Internet the connectivity of every single four facility of a company and communication among themselves can be realised, also including the production staff (Sung, 2017, p. 40)

In Lasi, Fettke, Feld and Hoffmann (2014, p. 239) Industry 4.0 is mainly unterstood as more or less the more advanced degree of digitization and automation first of all within a productive environment. It creates a digitised value chain, which also enables communication of products among each other, to the technical environment and different business partners. This specific definition was then taken over two years later, in 2016 by Oesterreich and Teuteberg (2016, p. 122).

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According to the "Plattform Industrie 4.0", from a more holistic and marketing side understands from the: "[...] 4th Industrial Revolution, a new degree of organisation and management of the whole added value chain, comprising entire product life cycles. This cycle is a result of increased, individualised expectations of the customers of today [...]". (Plattform Industrie 4.0, 2015, p. 3)

In paper of D. Müllmann (2018, p. 700) e.g. can be found a definition of 2 Industry 4.0 of the following content: "process of commercialised research, development, manufacturing, monitoring and recycling of product through horizontal and vertical digitization and in real time ability of communication of machines, which working autonomously, can be used more flexibly and because of the sensors are connected with the physical world. The aim is a profitable, economical in terms of used resources in production of smart products on serial scale nearly to the 1-lot, which similar as the production machines, deliver digital data according to their cycle life, for further optimization, development of future products and additional services".

As shown above, it is vain to seek for a universal, single definition for Industry 4.0. Till now this work has not been done, neither in one particular sector of industry, nor in the inter-disciplinarily manner (Mertens, Barbian, & Baier, 2017, p. 46). Therefore, the concept of Industry 4.0 is often criticised for its lack of concrete definition framing and is handled more as a trendy word (Mertens, Barbian, & Baier, 2017, p. 50), which is surely an unfair estimation of its advantages and meaning for a future way of manufacturing.

From all the definitions of Industry 4.0, presented above, first of all the definition of Müllmann fits in the best way the holistic description, where are also mentioned most of the main characteristic elements.

In the Figure 3 is shown the essence of Industry 4.0 with all the reasonable elements of an example of a smart factory (here: under burning glass), in which whole mindset of the Industry 4.0 can be implemented.

The most specific characteristic and range of the Industry 4.0 is its so-called horizontal and vertical integration (Stock & Seliger, 2016, pp. 536-540). According to Figure 3, horizontal integration comprises all the steps of the added value chain; starting from a certain group of all suppliers (on the left-hand side in Figure 3) and ending up at the consumers or customers (on the right-hand side in Figure 3). In case of vertical integration, it describes the smart connection of all the departments of a particular company, including all facilities and devices, which are also integratable, where the staff also plays a not unimportant part in this highly advanced social-technological system.

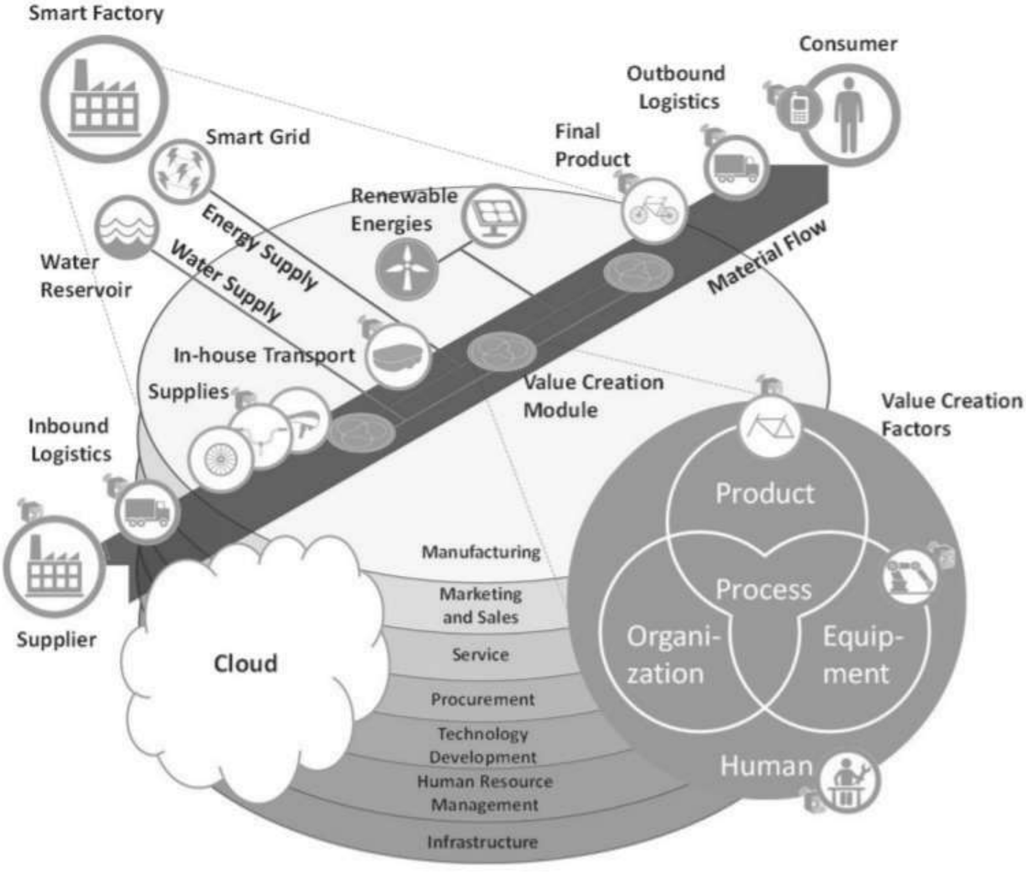

Figure 3: The macro perspective of Industry 4.0
Source: Stock & Seliger, 2016, pp. 538

4. THE KEY PILLARS OF INDUSTRY 4.0

Within the concept of Industry 4.0, there can be defined several characteristical elements, which are typical. For example, Kagermann et al. (2013, pp. 13-14) said that Industry 4.0 is mainly described through so-called cyber-physical systems, the Internet of Things (IoT), or cloud technology. Another scientific source mentions additionally also the smart factories, or the Internet of Services (Hermann et al., 2015, pp. 5, 7) (IoS), as the main elements of the 4th Industrial Revolution. Of course, this is only a small extract of the whole range of all features, Industry 4.0 contains. Even in this example can be seen the disagreement according to the most important elements of Industry 4.0.

In nearly each source of science (Fatorachian & Kazemi, 2018, pp. 3-15; Ganzarain & Errasti, 2016, p. 1122; Stock & Seliger, 2016, pp. 537-540; Sniderman, Mahto & Cotteleer, 2016, pp. 2-5; Aslanertik & Yardimci, 2019, pp. 550, 553) are mentioned almost the same digital technologies, being directly linked to the Industry 4.0. The most typical and frequently mentioned elements of it are shown in a figure below (Figure 4).

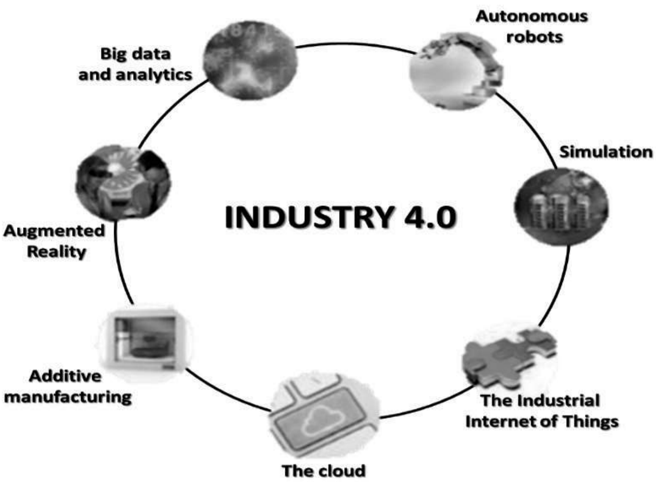

Figure 4: The key elements of Industry 4.0
Source: based on Rüßmann et al., 2015, p. 2

According to the figure above, overall in Industry 4.0 there can be defined seven key pillars, namely:

- The cloud
- The Industrial Internet of Things
- Simulation
- Autonomous robots
- Big data and analytics
- Augmented Reality
- Additive manufacturing (i.e. 3D printing).

In terms of completing the list above, in several sources is often mentioned the topic around cyber security, as also one of the pillars of Industry 4.0 (Dalmarco, Ramalho, Barros, & Soares, 2019, p. 3). Because this specific sphere is not very new and played also one of the most important roles in the time before the 4th Industrial Revolution, in this section it will not be discussed. In this paper cyber security will be mentioned only in the section "blocking points for successful implementation of Industry 4.0", the last but one section of this written work.

Because of the space limitations of this paper, "a priori" there had to be done a preselection of the elements presented. In the following are described more in detail only three chosen elements of the Industry 4.0, which are subjectively not so obvious in terms of understanding. The elements presented here are:

- The cloud (technology)
- Big data and analytics and
- The Industrial Internet of Things.

The cloud

In free translation, the term "the cloud" means simply a computing of data in a virtual space – in the so-called "cloud". The aim of cloud computing is the creation of a dynamic IT infrastructure, which according to the actual demand is adjustable (so can be increased or decreased depending on the actual requirements). Such a virtual space is able to offer e.g.: processing and network capacity, storage of data, even final software products, at any time, from everywhere and is always available in a sufficient amount. (Schwarzbach, 2016, p. 127)

The cloud can be also seen as an IT platform, which forms the spine of the whole networked digitization and enables the communication of all elements of Industry 4.0 (Landherr, Schneider, & Bauernhansl, 2016, p. 28). Such a network consists of single facilities, production machines, a group of such machines, even a whole factory. In a highly digitised system the transfer of data among individuals will last only few milli seconds, or even less (Rüßmann et al., 2015, p. 4).

BIG DATA & ANALYTICS

Thanks to big data and its analytics, the collection and analysing of data is enabled, which come from different sources, for example: production planning, industrial devices and facilities, other essential enterprise data, or selling results from the past. Through analysing data, it is possible to undertake decision making, even under real time conditions. (Rüßmann et al., 2015, pp. 2-3) Additionally, on basis of the collecting this past, historical information, the problems that appear can be analised, so that their probability of occurance in the future can be forecasted more accurately. Besides, thanks to prior experience, the staff will have the know-how, to tackle the obstacles that appear (Bagheri, Yang, Kao, & Lee, 2015), if necessary.

According to the definition of Forrester, big data consists in overall of four so-called "V's". There can be distinguished (Witkowski, 2017, pp. 767-768):

- **V**olume of data,
- **V**ariety of data,

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- **V**elocity of generation of data and
- **V**alue of data.

Via this new technology, the companies of the future will be able to generate additional value for themselves, while analysing the huge amount and diversity of digital data. This tool will give companies the possibility of better prediction, i.e. what will happen with the highest probability at the next (point in a given timeline horizon) and therefore an ability in a proper way to react and make (hopefully) the right decisions (LaValle, Lesser, Shockley, Hopkins, & Kruschwitz, 2011, pp. 27-28). Through big data and its analytics, it can also contribute to optimised processes inside a certain company. Thus, the minimising of so-called production interruptions, optimizing predictions prediction for future maintanance activities, or ability to produce demanded, customised products can be realised much more easily (Babiceanu & Seker, 2016, pp. 129-131), where even changing consumers' expectations can be better defined (Ghobakhloo, 2018, p. 15). Overall, thanks to big data technology the companies, which decide to use it for their daily business, may have advantages in terms of maintaining competitiveness in comparison to the other enterprises, which do not use this tool (Hu, Wen, Chua, & Li, 2014, pp. 672-675), or even think about it.

The Industrial Internet of Things

The (Industrial) Internet of Things (IoT) is the basic, infrastructural requirement to enable action in practice of Industry 4.0 (Pereira & Romero, 2017, p. 1211). Through the IoT, it is possible to create digital linking of real life with the virtual one. (Schwarzbach, 2016, p. 9) With the new technology of the IoT can be enriched nearly every device or facility, which can be then connected via digitization, and communication with each other by means of the standardised protocols is possible (Hozdić, 2015, p. 33). The units, which are able to be a part of the IoT, can deliver much more information, than solely data about the final state of products. With the IoT is also possible the tracing of the actual state of producing items within a given production line, and to know the manufacturing steps which are still needed. (Schwarzbach, 2016, p. 9)

In the scientific sources is also mentioned the term "Internet of Everything" (IoE), which on the one hand consists of the Internet of Service (IoS) and on the other hand of the Internet of People (IoP) (Neugebauer, Hippmann, Leis, & Landherr, 2016, pp. 3-4), thus ensuring the connectivity of the staff with the mechanised part.

5. CONTRIBUTION OF THE INDUSTRY 4.0 TO ENVIRONMENTAL PREVENTION

While not denying the advantages of Industry 4.0, which can be mainly seen in the improvements of the efficiency of processes, new ways of production, and digitization of many business processes, there can be also found some characteristics, which go together with environmental protection. In this section are discussed just a few examples (the cause of the paper limitations) of the Industry 4.0 contribution to ecological protection and its sustainability, which is more and more important, also for potential customers of the future. According to Industry 4.0, there is often mentioned a reduction of so-called greenhouse gases (Peukert et al., 2015). It has resulted in a decrease in consumed energy sources (Kagermann et al, 2013, pp. 62-65) (i.e. through the use of the smart grid (Jeschke, Brecher, Meisen, Özdemir, & Eschert, 2017, pp. 8-9)), the amount of waste, use of other resources (de Man & Strandhagen, 2017, pp. 721-726), and also a high rate of recycled materials (Herrmann, Schmidt, Kurle, Blume, & Thiede, 2014, pp. 283-288; Saurabhet al., 2018, p. 238).

Overall it is said, that Industry 4.0 contributes a significant input to ecology and its protection. It helps in two acheiving ecological sustainability of companies in almost every business sphere, i.e. production, logistics (where the total amount of transports or deliveries (Gabriel & Pessel, 2016, p. 134) can be minimised). In this way, through advanced automation and digitization it will be also possible to intensify the connection along the whole value chain (Oesterreich & Teuteberg, 2016, pp. 134-136), additionally improving and creating significantly more efficient processes (Bergmann, 2019, p. 17).

Industry 4.0 may also bring a company to rethink its form of whole supply chains. From this perspective, the "reshoring" strategy (Müller, Dotzauer, & Voigt , 2017) can play then a more important role, which is also seen as a form of deglobalisation. A strategy of reshoring is generally understood as 7 closing of plants of a certain company abroad, often in so-called low-budget-countries, which are mostly located in Eastern Europe, or in the Asian continent. The aim of building up plants in these particular geographical regions is mainly economic and is almost everytime driven by cost reduction, first of all on labour and therefore to increase the profit, also because of the stakeholders expectations. In the case of Industry 4.0, manufacturing of individualised products for sure will not be so labour intensive, as before and even today. There will be less staff needed (in the total amount) but higher educated. Thus, the main advantage of the countries of Eastern Europe and Asia would then suddenly disappear. Thanks to Industry 4.0, manufacturers may often think about moving back to home countries, where the final products are sold in a high volume. Additionally, this strategy can contribute immensely to environmental protection through the decrease in transportation costs and overall sustainable thinking. Also the still current pandemic COVID-19 may have an effect in the rethinking of the globalised supply chain, where supply of the specific to-assembly parts is not secured in each case.

The creation of long-lasting products through proper design may also have a positive effect on sustainable ecology (Stock & Seliger, 2016, pp. 539-540). In this context can be mentioned one of the new technologies – 3D printing (Rojko, 2017, p. 82). 3D printing, or in general additive production, as it is also defined (Laureijs et al., 2017), makes possible manufacturing of products of very different and difficult shapes, building it up layer after layer, without the creation of waste composed of used materials (Laureijs et al., 2017, p. 1; Dalmarco et al., 2019, p. 6), unlike opposite to a classic methods of fabrication, like the lathe, or sinking. The main advantage of 3D printing is its freedom in shaping the geometry (Ghobakhloo, 2018, p. 13), where can be used on nearly every material; from plastic to metal (Laureijs et al., 2017, p. 2). It also reduces use of resources like the need for the production of tooling, creation of prototypes and by the way the overall time needed from the first drawings till the final release on the market may be meaningfully minimised.

In Industry 4.0, thanks to use of sensors, it is possible to control the individual production machines (Walz, 2019, p. 14), certain production areas and even whole plant. In cases, where some areas don't produce, these can be automatically shut down, without any staff actions. In areas, which are fully automated, like the welding shop, which e.g. can run during a night shift without the lighting, especially, if staff is not needed, energy consumption can be saved in this way.

All these examples (which are only a small part), presented above, can play a contributing role in the reducing of energy consumption and additionally minimizing overall costs.

6. BLOCKING POINTS FOR SUCCESSFUL IMPLEMENTATION OF INDUSTRY 4.0

As with everything in real, professional life, all have their advantages but also a certain amount of disadvantages, which need to be dealt with and have to be always kept in in mind. The concept of Industry 4.0 plays not an exceptional role in this case. In following chapter of this paper are presented the most important issues in terms of implementing the solutions, coming clearly from the area of Industry 4.0.

Paradoxically, the main characteristic of Industry 4.0, which is clearly the Internet of Things, and also the digital networking of so-called cyber-physical systems (CPS), is on the other hand its biggest weakness for the whole of IT security (Dworschak & Zaiser, 2019, p. 81; Smart, 2019, p. 712; Benešová & Tupa, 2017, p. 2196) in terms of preserving the very sensitive data of every company (Rüßmann et al., 2015, p. 4; Thames & Schaefer, 2017, pp. 1-2). Obviously, the hazard of a being attacked by hackers is not a new phenomenon, but in the era of the 4th Industrial Revolution, where a very large number of digital data will be transferred from one spot to another, may put the tasks around ensuring cyber security to the most important test. This cyber security centered behaviour is highly likely in the nearest future. Those companies, who will not be able to afford cyber security to a sufficient high degree, will think twice about going in the direction of Industry 4.0, which will also mean the requirements of the implementation of horizontal and vertical integration, typical for the 4th Industrial Revolution. This on the other hand will require full transparency and openess for the sharing of sensitive, business data, even outside the factory's borders, along the whole value chain. Finally, in some countries, e.g. Germany, the topic regarding security of personal data is strictly regulated by the law, which overall in the end may also delay the implementations around Industry 4.0 (Smart, 2019, p. 714).

Till today, nearly every facility in a factory, no matter whether industrial robots, or other devices, come from different suppliers. Each with specific characteristics, based on non-standardized, so-called communication protocols (Kjellsson, Vallestad, Steigmann, & Dzung, 2009, pp. 4285-4287; Thuluva, Anicic & Rudolph, 2017, p. 2), often using different software (Rojko, 2017, p. 84). Without a holistic standardization in IT communication, connection within all CPS' could be hard to acheive.

The lack of digital competences within a company is another blocking point on a path towards the 4th Industrial Revolution. Not unusually there is no existing knowledge about Industry 4.0 even on a management level (Pirron, Schaffert, & Kopp, 2019, p. 117). Therefore, not surprisingly there is additionally not a sufficient number of well-educated employees (first of all) in digital objectives, who by the way in general also often show resistance against new circumstances, which e.g. in case of the Industry 4.0 take place (Karadayi-Usta, 2019, p. 974) .

Also plenty of companies have difficulty with estimating overall investments, necessary implementations for Industry 4.0 and not seldom are faced with a shortage of their financial resources (Dalmarco et al., 2019, p. 4; Karadayi-Usta, 2019, p. 2). The last one is especially critical for so-called small- and medium-sized entrepreneurs (SME), who obvously don't possess the resources on the same level, as global companies, not only in the financial sense.

As a summary of this section, below is showed a ranking of the ten most challenging topics (from companies's point of view in the decreasing order according to the importance) on a path towards transformation in a Smart Factory (Kiel, Müller, Arnold, & Voigt, 2020, pp. 247-248), an upgraded plant on the standards of Industry 4.0. These ten topics are:

1. Technical integration
2. Organisational transformation
3. Data security
4. Increasing of overall competition
5. Collaboration along the whole added value chain
6. Low rate estimation of the benefits from the implementations of Industry 4.0
7. Financial resources needed
8. Well-educated human resources needed
9. Public environment (i.e. the infrastructure of Internet (speed of data transfer)), or law situation regarding security of personal data (often country-related) and
10. Centralisation on customers' expectations.

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CONCLUSIONS

Throughout the preceding paper, the intention was to sketch briefly some areas of the normally very large range of capturing of Industry 4.0, that can also contribute to ecological protection. It is simply not possible to present all the relevant topics of Industry 4.0, which may influence the surrounding environment in a better way. In other words, this is the main limitation of this work. Nevertheless, even if Industry 4.0 has not been discussed in that bright spectrum, as it undoubtedly deserves, it could show a few of its beneficial advantages in terms of ecological sustainability together with daily, professional life in the environment of Industry 4.0.

The general term of the 4th Industrial Revolution in describing Industry 4.0 is not groundlessly named as a Revolution. It shows its importance for the whole of industry, regardless of the industrial sector. Industry 4.0 is characterized through its centralization on digitization (which urgently started in the 1970's, as the beginning of the prior, 3rd Industrial Revolution) and the fast development of new technologies, like big data, cloud technology, connectivity and all the important elements within and beyond the plant's borders, which additionally tighten meaningfully the collaboration of all the single actors of a holistic supply chain. In general, according to globalized supplying, Industry 4.0 may also contribute to a fully opposite trend, called reshoring, which was also discussed in this paper. This particular term covers all the activities, concentrating on giving up the plants abroad, in so-called low-budget-countries, where the structure of labour costs are significant lower, than in developed countries, like in Western Europe, like Germany. It is well known, that in the times of Industry 4.0 the overall amount of employees will not be as high as nowadays. Therefore, the most important advantages of the low-budget countries will disappear. This circumstance may lead to decreasing of deliveries in total, which finally results in less pollution of the ecological environment.

Described above is just one example of the positive impact of Industry 4.0 to the protection of the ecology is just one but not the only single example. Other possibilities of putting less burden of the ecology are e.g. the usage of so-called smart grids, new methods of manufacturing, which could provide immense saving of consumed resources and by the way speed up the time needed for the releasing of products onto the market towards consumers, who now desire highly individualized offers.

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