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# THE IMPACT OF EMERGING ENVIRONMENTAL ISSUES ON THE EUROPEAN ENVIRONMENT AND THEIR IMPLICATIONS FOR EUROPEAN ENVIRONMENTAL POLICY: ARTIFICIAL MEAT, BLOCKCHAIN, DRONES FOR DELIVERY, AND OFF-GRID ELECTRICITY

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## Abstract

This paper analyses four specific technological innovations — artificial meat, blockchain, drones for delivery, and off-grid electricity — by looking at them as weak signals and emerging issues with potentially positive and negative impacts on the environment. They are arising at a remarkably fast pace and this work examines the patterns of their emergence. The main purpose of this paper is to challenge the dominant view on their probable future and stimulate policymakers to consider their alternatives, and ultimately increase policymaking resilience. The analysis is based on a systematic review of available academic and non-academic literature, with the aim of synthesising obtainable knowledge on each of the considered technologies and enabling a broad understanding of potential threats and opportunities related thereto.

Reduction of the total greenhouse gas emissions, improvements in energy efficiency, decreased pressure on limited natural resources, and increased protection of ecosystems are the main areas to which the selected technologies could make an important contribution. Yet, the complexity and the wide array of risks associated with their diffusion challenge the conventional view that technological innovations are the panacea for global environmental problems. We argued instead that potential risks and threats related to their dissemination must be addressed through adequate policies, adopted in a timely manner, and founded upon extensive research.

## Keywords

new technologies, European environment, emerging issues, weak signals, artificial meat, blockchain, drones for delivery, off-grid electricity.

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## I. Introduction

At this moment in time the overwhelming majority of the world's human population already live in the shadow of manifold environmental problems and many people have experienced the associated detrimental effects, such as heatwaves, extreme weather conditions, or food insecurity. Environmental risks multiply and environmental stresses amplify at an increasing speed, a state of

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affairs evidenced by the comprehensive reports released by the Intergovernmental Panel on Climate Change (IPCC, 2018) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). Technological innovations and their swift dissemination are commonly at the centre of measures proposed to ensure that humanity does not fail to preserve the single chance to remain within the finite environmental limits of our planet (Jackson, 2009). Environmentally friendly technologies are envisaged to claw our path towards a low-carbon economy by enabling considerable reduction of all greenhouse gas emissions (GHG) responsible for human-induced climate emergency. Yet, their application might result in a variety of unintended consequences. Thus, governments and institutions, in an increasing fashion, employ horizon scanning to identify emerging issues with potentially substantial impacts on the environment in order to encourage policy-relevant and practical research on those issues in support of designing effective preventative approaches and precautionary measures (Sutherland *et al.*, 2011).

This paper examines four new technologies identified by the European Environment Agency (EEA) horizon scan as being emerging issues: artificial meat, blockchain, drones for delivery, and off-grid electricity. The analysis focuses on the patterns of their emergence. Although their advent is characterised by complexity, only little science and direct hindsight exist to assist the management of these emerging technologies. This work argues that while these technologies can offer significant opportunities to generate environmental benefits, adequate policies based on extensive further research must be adopted prior to their wider application so as to avert the potential risks and threats to the environment.

To begin with, we discuss the importance of looking at new technological innovations as weak signals and emerging issues. While the methodology is explained in the second section, the following section consists of a detailed examination of each of the analysed emerging issues. Outcomes are considered and the main findings outlined in the fourth section.

## **II. New technological innovations as emerging issues**

Mounting evidence suggests that human activity is irreversibly damaging the natural world and posing existential threats to human society. The IPCC (2018) in its report warns of the adverse impacts of climate breakdown, such as extreme weather conditions, accelerated biodiversity loss, and greater risk to human health, the water supply, food security, livelihoods, human security and

economic growth. All of these are to be experienced already at the global heating of 1.5°C above the pre-industrial level and considerably amplified should the average global temperature increase to 2°C above the pre-industrial level. In addition, according to the IPBES (2019), 75% of land and 66% of oceans have already been eroded due to food production significantly altering Earth's ecosystems and pushing many species of plants and animals into extinction. Continuing down this path, we risk exceeding Earth's finite ecological limits in the coming decades (if we have not already done so) and causing irreversible damage to the natural environment.

Urgent actions are needed if we are to prevent the worst anthropogenic impact on our planet. According to the IPCC (2018), to keep global heating below 1.5°C, global emissions of carbon dioxide (CO<sub>2</sub>) and all GHG emissions need to be reduced to zero by 2050 and 2060–2080, respectively. Radical transformation of global energy systems and rapid decarbonisation of all sectors, including transportation, construction, industry, agriculture and forestry, are required (IPCC, 2018). Enormous investments in new environmentally friendly technologies are necessary (Godthab *et al.*, 2019). Research, development and swift deployment of low-carbon technologies around the world are deemed to be essential should we succeed in reducing cumulative global CO<sub>2</sub> emissions without sacrificing economic growth (Stern, 2009). Indeed, the apparent inability of policy to manage the issues of population growth and increased income leads some to believe solely in the role of technological advancements in averting the anticipated environmental catastrophe (Jackson, 2009). Thus, technological innovations seem to be the key to achieving the desired transition in the foreseeable future.

A similar position towards new technology has been adopted by the European Union (EU). Outlining its vision for 2050 as 'living well, within the limits of our planet', the EEA recognises the great significance of the principal economy sectors' transformation for the future of the European and global natural environment, and emphasises further investment in new low-carbon technologies (EEA, 2015). Yet, the EEA (2013) urges against the unfettered application of new technologies, as science and global industries might be tempted to introduce them without a comprehensive understanding of their full consequences for the social and natural worlds. In situations in which governments exercise ever less control over globalised technologies, employment of any new innovation needs to be balanced by precautionary measures so as to impede the hazardous impacts on the natural environment (EEA, 2013). Forward-looking assessment, as a part of foresight work, also called future studies, can prove to be an indispensable source of information for this purpose.

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The task of future studies is prospection, which means creating images of the future through systematic, conscious and explicit employment of prospective thinking and methods (Voros, 2006). In the conditions of growing complexity, insecurity and dynamic evolution of the global environmental problems, forward-looking assessments focused on the application of new technologies can provide policymakers in advance with long-term information that can enable them to develop appropriate environmental policies and prepare them for making timely decisions (EEA, 2011). For this purpose, at the European level, in 2011 the EEA established the knowledge base for Forward-looking Information and Services (FLIS). The main aim of FLIS is to add new forward-looking elements to the already existing EEA knowledge base (EEA, 2011). One of the instruments at the disposal of FLIS is the identification of warning (weak) signals of emerging issues.

First introduced by Igor Ansoff (1975) in the context of a future-oriented approach to planning in business and institutional settings, the concept of weak signals has been integrated into future studies only more recently (Halopainen & Toivonen, 2012). Weak signals are signs of emerging issues, or “*signals of possible change*” (Hiltunen, 2007). That is to say, they indicate the issues that are emerging (Hiltunen, 2008). They concern events that have not been important or influential in the past or at the time of inquiry, but that might be crucial for the emergence of the future. By examining such events as soon as they first appear (just as a sense of threat or opportunity), and well before they become an ordinary occurrence, foresight work aims to understand new processes started and map alternative futures (Halopainen & Toivonen, 2012). This can significantly improve the adaptability and increase the flexibility and resilience of policymaking (Inayatullah, 2013). Above all, weak signals and emerging issues analysis can help to prepare decision makers to act in creative and innovative ways.

Whilst negative anthropogenic impacts at the global level have been increasing at a high speed, investment in new environmentally friendly technologies and their quick dissemination have been recognised as being crucial for achieving the transformation into a low-carbon global economy. Yet, prior to their application, every effort should be made to understand the possible consequences of new technologies for the natural environment and the social world. Future studies allow us to look at new technological advancements as emerging issues. Information obtained in this manner can help policymakers to identify potential future risks and, thus, avert irreversible harm. Overall, unforeseeable and unpredictable consequences of climate emergency and wildlife extinction prompt us to act with every precaution when considering any new technological innovation.

### **III. Methodology**

In the following chapter, four weak signals are analysed: artificial meat, blockchain, delivery drones, and off-grid electricity. They have been identified by the FLIS working group via a horizon scan in 2018 as being emerging issues related to the transformation of three consumption–production systems: food, mobility and energy. Analysis was then conducted and completed by the Institute for Forecasting at the Slovak Academy of Sciences in 2019.

To examine each of the weak signals a systematic review of available literature was carried out. While the main focus of the review was on the EU-relevant information, it was not restricted thereto. The aim was to produce a succinct forward-looking assessment in the form of a factsheet that would synthesise current available knowledge on each of the selected emerging issues and facilitate a broad understanding of possible threats and opportunities related thereto. In particular, attention was paid to less-known but potentially high-impact implications of these new technologies for the EU environment and environmental policy.

Some limitations related to this study exist. The examination consisted of reviewing both available academic and a variety of non-academic sources, including websites, blogs, newspaper articles, and so on. While such a methodological approach is commonly applied in future studies when analysing emerging issues (Inayatullah, 2013), the sources employed inexorably influence the analysis produced. Because of the limited scope and space of this paper, the analysis presented here narrowly concentrates on the processes initiated. It proceeds neither to the outlining of alternative futures nor to the ‘making’ of a desired future.

Based on the template elaborated upon by FLIS in previous years, each of the assessments consists of the following parts: description, overall impact, impact on the European environment, and implication for environmental policy in Europe.

### **IV. Emerging issues**

#### **IV.I Artificial meat**

##### Description

The term ‘artificial meat’ first appeared at the beginning of the 20<sup>th</sup> century in referring to plant-based food (soya beans, wheat, a variety of legumes, cereals or fungi), and only at the start of this millennium did it begin to be applied to meat produced from the cells of real meat. This was originally produced in the laboratory and called *in vitro* meat. Artificial meat, alongside other commodities such as artificial leather, hen-free egg whites, artificial milk, rhino horns, and so on, falls into the category of ‘cellular agriculture’, which focuses on the production of agricultural products from cell cultures (Post, 2012). Other names for artificial meat in use include the following: laboratory-grown meat, synthetic meat, or clean meat. Lee (2017) puts forward the following definition:

*“In-vitro meat involves injecting muscle tissue from an animal into a cell culture, allowing cells to ‘grow’ outside the animal’s body.”*

This process uses stem cells from living animals that are put into a serum, wherein they start growing and multiplying. In approximately three months, meat suitable for eating is formed. In theory, one cell could be used to grow an infinite amount of meat. The process is considerably faster than more traditional meat production, which can last up to or more than a year depending on the particular kind of meat (Lee, 2017).

Several issues with laboratory-grown meat exist. The first problem relates to the accessibility of culture medium stimulating the growth of stem cells, which consists of sugar, amino acids and animal serum. The animal serum is prepared from foetal bovine serum (FBS), which is an animal by-product. This is the liquid component of the blood from a calf’s foetus after it has been depleted of red blood cells, fibrin, and clotting factors (Lee, 2017). The FBS is used because it has an optimum composition of hormones, growth factors and other ingredients necessary for optimal growth and life of the cells. Yet, FBS culture medium is very expensive, which hinders the mass production of laboratory-grown meat. More economical *in vitro* meat production would require an alternative low-cost way of fabricating enough culture medium in an artificial way. While some FBS-free products already exist, this remains the focus of research in cultured meat startups (Lee, 2017). The second problem concerns the high costs of artificial meat production. The first hamburger grown by Dutch University was priced at €250,000 in 2013 (Sacham, 2016). Since then the production costs have decreased to tens of euros and are expected to decline further, reaching the cost of conventional meat eventually. Potential artificial meat producers, such as *Memphis Meat* or *Mosa Meat*, aspire to offer competitively priced products by 2020 (Ireland, 2017). Nevertheless,

future research is to concentrate on inventing artificial blood with a similar composition to that of real blood and which is capable of providing stem cells with the energy necessary for their growth.

### Overall impact

Several far-reaching consequences in social, environmental, economic and technological domains need to be considered in relation to the further evolution and widespread use of artificial meat. Even if the artificial meat were to be introduced to the market now, the question of its acceptance by the general public would persist. For instance, as of 2019, genetically modified organism products were accepted in the USA but not in Europe (Hocquette, 2016; Johnson *et al.*, 2018). Thus, a survey conducted by Michigan State University (MSU, 2018) in the USA found only 33% of its participants willing to purchase products looking and tasting identically to meat but produced artificially, in comparison to 48% refusing to do so. After receiving further information on artificial meat, 60% of respondents were in favour of trying *in vitro* meat, while 25% still rejected to eat it regularly (MSU, 2018). In Europe, the acceptance of laboratory-grown meat varies considerably. It is somewhere between 16% and 66% (Wilks & Philips, 2017), which could also be attributed to ongoing dramatic changes in the eating habits of Europeans (Fernandéz, 2018). Reduced consumption of ‘real’ meat and an increasing preference for vegetable-based dishes could also potentially contribute to the improved acceptance of *in vitro* meat.

The major advantages of the introduction of artificial meat can be expected in animal welfare and the health of the human population. Sachan (2016) notes how at present the majority of farmed animals exist in poor conditions, leading them to destruction amongst themselves. Diseases spread quickly in overcrowded spaces, requiring treatment with antibiotics or other medicines. In the USA, 80% of antibiotics produced are used on livestock (Sachan, 2016). Such substances can then be transferred to human bodies and induce their resistance to antibiotics, putting people at risk of infection from antibiotic-resistant microbes. A similar situation might be observed with the indirect consumption of growth hormones via animal products. The animals are administered various hormones in order to grow bigger in specific parts of their body according to the requirements of consumers (Mattic & Allenby, 2013). All of this has repercussions for human health.

On the contrary, several indications of rather positive benefits of artificial meat to human health exist. As Mattic & Allenby (2013) note, artificial meat production requires stem cells from healthy animals free of medication, while the process of meat production in sterile conditions needs no



antibiotics. A strictly controlled production process can diminish the incidence of zoonotic and food-borne diseases. Reduced indirect intake of antibiotics by humans through meat consumption could result in less bacterial resistance to antibiotics and a lower propensity for animal diseases to cross to humans (Mattic & Allenby, 2013). Moreover, considerably shorter artificial meat production, in comparison to ‘real’ meat (Lee, 2017), could make the use of hormones redundant. Production could concentrate on the growing of quality and selected organs only, eliminating those parts that have less or no utility to humans and, thus, making the whole process considerably expeditious. Furthermore, as the production is controlled and the composition of artificial meat regulated, the fat content can be set at a required level, harmful saturated fats can be replaced by healthier omega 3 fatty acids, and some kinds of healthy ingredients, such as vitamins, could be included in the meat (Bhat *et al.*, 2015). Thus, as Post (2012) concludes, *in vitro* meat could be a healthier alternative to conventional meat.

All in all, while such transformation in meat production could have an overall positive effect on people’s health, the requisite of healthy stem cells could intensify the pressure placed on farmers to provide the reared animals with better living conditions. In turn, improved animal welfare may increase the acceptance of artificial meat, particularly amongst those people who refuse to eat meat just because of animal ill-treatment and the misuse of antibiotics, hormones and other substances in meat production. Moreover, further benefits for people might lie in increased prosperity — for those from the Global North in improved nutritional value of ingested meat, and for those from the Global South through reduced illness due to malnutrition.

Nevertheless, several risks are directly related to the wider use of *in vitro* meat. Thus, the reduced cost of final products induced by improved production efficiency might stimulate consumption or even trigger meat overconsumption, whereby leading to obesity and health problems (The Week, 2018). The process of production through animal-based serum involves the risk of contamination (Orzechowski, 2014). Last but not least, it is not entirely clear as to what such transformation of meat production could mean for the agricultural labour market. What is more, decreased use of chemical substances might have implications for other sectors, such as the pharmaceutical or chemical industry.

#### Impact on the European environment



The spread of artificial meat production can have significant implications for the European environment, related mainly to GHG emissions, the use of natural resources, fertiliser application, and land use changes. Earth's human population have experienced a dramatic increase from 2.5 billion in 1950 to the present 7.5 billion, being expected to reach 10 billion by 2050 (UN, 2013). This has been accompanied by increasing consumption of meat. The demand for meat is expected to grow further by 73% by 2050, from its level in 2010 (FAO, 2011). The EU (2018) in a recent report claims that livestock raised for meat already uses 30% of global ice-free terrestrial land and 8% of freshwater resources. Thanks to the fast-growing world population, the percentage of land use is to climb to 50% by 2050 (EU, 2018). Consequently, Earth's finite natural resources are likely to remain under increasing pressure from conventional meat production.

First and foremost, meat production is an important contributor to climate emergency. Gerber *et al.* (2013) note that the livestock sector is responsible for 14.5% of all human-induced GHG emissions, while 65% of the amount is due to the feeding of cattle and dairy products. Livestock is, through ruminants, also accountable for 37% of all global methane emissions (FAO, 2006). Yet, the transition to artificial meat production seems to have the potential to reduce the total amount of such produced GHG emissions. Several studies (Tuomisto, 2011; EU, 2018) claim that *in vitro* meat production is more environmentally friendly and more energy-efficient than traditional farm-grown meat. However, the technology for artificial meat mass production still does not exist. Thus, some uncertainty remains regarding its actual potential to reduce GHG emissions (Ireland, 2017). It is estimated that artificial meat is 7–45% less energy-demanding and produces 78–96% less GHG emission than conventionally produced meat in Europe (Tuomisto *et al.*, 2011). Yet, further research is necessary to confirm this.

The reduction of livestock means saving resources such as water and land. It is estimated that the transition to artificial meat production could mean a 99% reduction in land use, as well as a 82–96% decrease in water use, depending on the product (Tuomisto *et al.*, 2011). This might relieve the pressure to enlarge existing cultivated areas. Indeed, according to Bhat *et al.* (2015), more water and land could be available for other more environmentally friendly kinds of production, e.g. ecological agriculture. Some land could even return to the wilderness for the purpose of biodiversity conservation and endangered species protection. Wildlife could further benefit from the decreased use of fertilisers and other chemical substances widely applied in the agricultural production of animal feed, such as cereal and fodder plants (Bhat *et al.*, 2015). Yet, some areas, including

mountain pastures in the Alps and the Carpathians, environmentally profit from traditional forms of cattle and sheep breeding. Here, traditional livestock farming contributes to the conservation of biodiversity and the reduction of livestock could result in serious environmental damage (Battaglini *et al.*, 2014). Thus, although European nature might greatly benefit from the transition towards laboratory-produced meat, it would be necessary to ensure that potential negative consequences are being adequately addressed.

#### Implications for environmental policy in Europe

Considered in the context of the EU 2050 vision of ‘living well, within the limits of our planet’ (EEA, 2015), a shift towards artificial meat production could make a significant contribution to the fulfilment of EU and global economic, social and environmental goals. Presumed decreased pressure on natural resources can improve the protection of EU ecosystems and, thus, help to implement the targets for biodiversity protection as set out in the EU Biodiversity Strategy to 2020 (EU, 2011). It could further prevent land degradation, which was one of the aims of a new bioeconomy strategy for sustainable Europe announced by the European Commission (EC) in October 2018 (EC, 2018b). Investment with which to enhance the production process of cultivated meat would be in line with the objectives of the Environment Action Programme 2050, calling to stimulate innovation to speed up green growth (EEA, 2017). Last but not least, *in vitro* meat could contribute to better food security, as required in the 2030 Agenda for Sustainable Development (UN, 2015), as well as help to fulfil the United Nations (UN) sustainable development goals (SDGs), especially zero hunger, good health and well-being, and responsible consumption and production.

All in all, the transition to artificial meat production presents important opportunities for the EU and global natural environment; however, adequate and comprehensive EU environmental policy is essential in order to accompany the innovation process and ensure the sustainable character of *in vitro* meat production in all of its facets.

## **IV.II Blockchain**

### Description

Blockchain technology, which is one of the digital ledger technologies, is closely connected to cryptocurrencies. Introduced in 2008 to serve as a public transaction ledger for Bitcoin, it has been further promoted by its success (ENISA, 2019), extending its impact well beyond the realm of currency (Boucher *et al.*, 2017). The European Union Agency for Network and Information Security (ENISA) defines it as follows:

*“...a public ledger consisting of all transactions taken place across a peer-to-peer network. It is a data structure consisting of linked blocks of data, e.g. confirmed financial transactions with each block pointing/referring to the previous one forming a chain in linear and chronological order. This decentralised technology enables the participants of a peer-to-peer network to make transactions without the need of a trusted central authority and at the same time relying on cryptography to ensure the integrity of transactions.”* (ENISA, 2019)

Blockchain is a technology-based system that stores data as a chain of blocks. The chain is composed of blocks that represent recorded transactions, with each new block of transactions being linked to the previous blocks (Nakamoto, 2008). ‘Mining’ is the term used for describing the work through which the chain of blocks (that forms a blockchain ledger) is created. To add a block of transactions to a blockchain, the ‘miner’ needs to find a solution to a difficult mathematical problem (hashing) (Boucher *et al.*, 2017). Blockchain has a decentralised structure. This means that in the absence of a central authority, where equal access to the same copy of ledgers is shared by all network participants, every new update requires approval by consensus, being voted upon or validated by the majority of participants. To ensure security, each block has a timestamp as well as a unique hash value (block header hash) referring to the previous blocks in the chain. The chain is composed of cryptographic structures that allow its identity to be verified while eliminating unauthorised alteration. Alteration can only be achieved through the consensus of network members. These features of the blocks enhance trust amongst participants. Traceability and information transparency are also guaranteed. Copies of ledgers with updated transactions as well as complete histories of all transactions are equally visible to all participants. Immutability of the blockchain data and the information that it contains is achieved by allowing the new addition of records to ledgers but not their modification or removal. In addition, the validation of transactions and subsequent additions to ledgers is facilitated by the use of smart contracts, which are essentially computer codes containing the terms of contracts and business rules, stored on the blockchain platform. These are executed automatically and without the need for human intervention or

judgment. In general, we distinguish between public ('permissionless') and private ('permissioned') blockchains depending on whether they are accessible to anyone or to only a limited group of people (Kouhizadeh & Sarkis, 2018). When public access is enabled the control of transactions in the blockchain is decentralised and transparent; when access is limited by the private mode, control is retained by a restricted number of persons (Boucher *et al.*, 2017).

In spite of a degree of scepticism towards cryptocurrencies such as Bitcoin, blockchain has already attracted the interest of the European business community and European institutions as a new business process. Beyond the financial sector, wherein its origin lies, the technology could potentially be extended over a great range of other areas, including governance, commerce, healthcare, education, logistics, and so on (ENISA, 2019), although further research and innovation would be required. Finding the solution to reducing the energy consumed during 'mining' is essential. Swapping the existing consensus mechanism, also known as the 'proof-of-work' algorithm, for alternatives (including 'proof-of-stake', 'proof-of-authority' and 'proof-of-elapsed-time' algorithms) has already been suggested (Jones, 2017). However, a thorough assessment of each mechanism, energy impact and energy efficiency is still required (European Parliament, 2018). Switching to greener sources of energy and the evolution of less energy-demanding computation are also options to be further explored (Jones, 2017). Sources of volatility (related to cryptocurrencies), security of personal data in the digital environment, security of the technological infrastructure used by blockchain platforms, and the enforceability of smart contracts within the Digital Single Market also need careful attention (European Parliament, 2018).

#### Overall impact

The main implication of blockchain technology is the shift of control (and trust) from a centralised authority to decentralised user networks and the reduction of intermediaries from the transactions performed. Decentralised information datasets could be updated through consensus and trusted by everyone, which would lead to a higher level of accountability (Kouhizadeh & Sarkis, 2018), and perhaps democracy (Boucher *et al.*, 2017). For example, blockchain applied in the election process could transfer the logging and verification tasks from a central electoral authority and distribute them amongst voters. This could foster development towards a more participatory and decentralised society. For example, blockchain-based e-voting was applied to internal elections within a political party in Denmark (Boucher *et al.*, 2017). In addition, the use of smart contracts lessens the need for the involvement of various intermediary professionals (such as legal or financial) and introduces the

automation of some processes (e.g. payment execution), thus further reducing the costs and time of transactions (Kouhizadeh & Sarkis, 2018) and improving services by reducing bureaucracy (European Parliament, 2018). The application of blockchain technology in public administration can benefit users by allowing them to create records (e.g. land registries, birth certificates) without the unnecessary involvement of any public administration officials (e.g. notary). Such a blockchain-based system has been tested in Estonia, wherein people were allowed to use their IDs to access a large variety of digital services (Boucher *et al.*, 2017). Numerous other applications of blockchain already exist, such as the protection of authorship and copyright of digital arts (*Ascribe* project), the prevention of internet censorship (alternative verification of DNS registration by *Namecoin*) (Shawn, 2015), and so on. It is claimed that the main positive impact of blockchain technology on European society is that of the enhanced transparency of transactions and more secure, cheaper and faster ways of keeping records (Boucher *et al.*, 2017). An understanding of the benefits that blockchain offers is usually based on the assumption that the information stored on a blockchain is public, accessible, shared and auditable (EC, 2019a).

Nevertheless, several concerns arise in relation to the wider application of blockchain technology. As the case of cryptocurrency Verge demonstrates, smaller blockchains based on the 'proof-of-work' algorithm can be sensitive to malicious attacks (such as the so-called 51% attack) from 'miners' taking advantage of errors in the blockchain protocol in order to modify transactions recorded with the purpose of seeking benefits (e.g. financial) for themselves (Sedwick, 2018). Moreover, by using great computational power, 'miners' can compromise the decentralised character of the blockchain and exercise considerable power and control over the 'mining' process (Shawn, 2015). In conditions in which the cryptographic nature of blockchain platforms may prevent legitimate institutional protection (e.g. law enforcement), decentralised blockchain-based systems can suffer misuse from external powers and evolve into oligarchies (Boucher *et al.*, 2017). In addition, decentralised blockchain-based systems are able to operate across borders (diffusing institutional accountability and legal responsibility), which may complicate their control by central authorities (Boucher *et al.*, 2017). For example, this might facilitate the use of blockchain technologies for illicit purposes, including the use of cryptocurrencies for money laundering and tax evasion (Houben & Snyers, 2018). The elimination of intermediaries raises questions in respect of central authorities losing their power, income and control, leading to possible conflicts of interest (ENISA, 2019), while the automation of the process brings into focus the issue of changes (reduction or alterations of tasks performed) in the patterns of 'white-collar' employment (Boucher

*et al.*, 2017). Security, privacy and data protection concerns are related to the possibility of tracking down the identity of individual users. The more personal data is stored on the blockchain, the easier it is to discover to whom it belongs (Boucher *et al.*, 2017). Last, but not least, is the issue of accessibility and equity, important within the context of sustainable development goals. Not all European citizens may have access to the Internet or the services provided by blockchain-based systems (Boucher *et al.*, 2017), or they could be disadvantaged by a lack of knowledge and expertise on blockchain technology fundamentals and its practical application (ENISA, 2019).

Despite the challenges and concerns, the overall impact of the wider use of blockchain technology on European society might be significant. As Shawn (2015) puts it, blockchain technology, by working on a larger scale, reducing friction and increasing efficiency, represents a paradigmatic shift in organising activity.

#### Impact on the European environment

The current application of blockchain technology indicates that its wider use might accelerate energy consumption and generate an increase in the production of GHG emissions. The process of transaction verification, or ‘mining’, through which cryptocurrencies are generated, is energy-demanding (Mougayar, 2016). The problem is closely related to the energy intensity, and thus unsustainability, of the commonly used ‘proof-of-work’ algorithm. The process of finding the solution to a complex mathematical problem (hashing) and value verification requires much processing power and, thus, electrical energy (Vries, 2018). This is best demonstrated in the case of Bitcoin. In 2017 the energy spent on ‘mining’ Bitcoin was suggested to exceed the requirements of tens of countries for all of their energy needs (Jones, 2017). Vries (2018) estimated the annual energy consumption of the Bitcoin network to be 2.55 gigawatts in 2018. He claims his results to be based solely on the number of hash operations that take place per second in the Bitcoin network (leading players in so-called Bitcoin mining to keep a low profile with regard to hardware, computing power and power consumption). He also predicts the energy consumption of the Bitcoin network to reach potentially 7.67 gigawatts in the near future as a result of the network expansion. By comparison, the annual energy consumption of Ireland is approximately 3.1 gigawatts and of Austria approximately 8.2 gigawatts (Vries, 2018).

When compared to alternative payment methods, in 2017 Bitcoin was claimed to be 20,000 times more energy-intensive than Visa (Brosens, 2017). In 2017 the energy consumed per transaction



was estimated to be 200kWh for Bitcoin, 37kWh for Ethereum cryptocurrency (also based on the ‘proof-of-work’ algorithm), and only 0.01kWh for Visa (Brosens, 2017). In 2019, the value for Bitcoin increased to 413kWh per transaction, which is equal to electricity that could power approximately 14 households in the USA for one day (Digiconomist, 2019). However, the ‘proof-of-work’ algorithm, or the hybrid ‘proof-of-work’ and ‘proof-of-stake’ algorithm, continues to be the most common algorithm used by cryptocurrencies, according to which calculations are carried out by electronic devices, thus relying on energy consumption (Jingming *et al.*, 2019). Although further studies on energy consumed by blockchain-based systems, beyond Bitcoin, remain scarce (Jingming *et al.*, 2019), the more complex these systems are, the more processing power they need for ‘mining’ and maintenance (Boucher *et al.*, 2017). As the majority of energy is still generated from fossil fuels, which produce greenhouse gas emissions, the energy intensity of blockchain technology can pose a threat to the global environment (Galeon, 2017) and could affect many countries in not reaching their climate change (Truby, 2018) and air quality targets and obligations. For instance, Bitcoin’s annual carbon footprint is estimated to be 22,813kt of CO<sub>2</sub> (Digiconomist, 2019). Thus, a broader application of blockchain, without resolving the problem of excessive use of power and energy required by ‘mining’, might compromise the EU’s effort to combat the negative impacts of climate breakdown and save the planet.

Notwithstanding this issue of energy consumption, the environment can also benefit from the technology, especially from the transparency and traceability of information introduced by a wider application of blockchain to existing processes. One such case is the use of blockchain by supply chains. Blockchain allows information on the origin of a product or process, and on the parties involved in its transactions and logistics, to be visible and verifiable by all supply chain partners (Kouhizadeh & Sarkis, 2018). Thus, for example, the application of a blockchain technology supply chain allows the clients of *Everledger* to trace the origin of diamonds from mines to stores (Boucher *et al.*, 2017) and the customers of *Walmart* to track the food that they buy along the supply chain (Aitken, 2017). What is more, as the information is secured and timestamped, it cannot be altered or modified, which eliminates possible fraud. Consequently, this can help to apply sustainability criteria on supplier and vendor selection, improve supplier development programmes, and achieve more sustainable purchasing by selecting more environmentally friendly materials and products, more sustainable designs of logistics networks, and sustainable production and internal operations (Kouhizadeh & Sarkis, 2018). Blockchain technology can also be employed in other applications with environmental benefits. Park *et al.* (2018) envision the technology being used for



the development of an energy platform within a smart home environment, enabling efficient electrical energy transactions between prosumers (i.e. individuals who are both producers and consumers of electricity) that could bring economic and environmental benefits.

#### Implications for environmental policy in Europe

On a global level, the UN Climate Change Secretariat initiated and supported the creation of the Climate Chain Coalition (CCC). The purpose of the CCC is to enhance the collaboration amongst its organisational members and stakeholders to support the application of blockchain for climate action and sustainability (UNCC, 2018). In Europe, the EU Parliamentary Committee on Economic and Monetary Affairs concluded that the regulation of blockchain is not an immediate concern, emphasising the focus on its monitoring (ENISA, 2019). In light of this, in 2018 the EC launched the EU Blockchain Observatory Forum (EC, 2018a). This is set to map key initiatives and monitor developments related to blockchain technology. The European Parliament, in its resolution 2017/2772(RSP), calls for a regulatory framework that would encourage further innovation and remove existing barriers to blockchain applications. Moreover, it emphasised the need for awareness raising and the education of citizens regarding the technology (2018). It also seems essential that any new regulation related to blockchain addresses the concerns surrounding its energy consumption and facilitates ways in which its application promotes, enhances and upholds the principles of sustainability.

### **IV.III Delivery drones**

#### Description

Drones, which were originally developed and used mainly for military purposes, have, during the course of the last decade, found their way into many areas of the civic sector. First patented in 1898 and converted into a mechanism in 1951, quick evolution of drone technology has occurred in the last 10 years (Molina & Oña, 2018). Although referred to in literature as a remotely piloted aircraft system (RPAS), unmanned aircraft vehicles (UAVs) or unmanned aircraft systems (UASs), drones are commonly defined as flying objects, or ‘robots’, with no pilot on board (Santamarina-Campos, 2018). According to the definition proposed by the European Aviation Safety Agency (EASA), a drone is:

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*“...an aircraft without a human pilot on board, whose flight is controlled either autonomously or under the remote control of a pilot on the ground or in another vehicle”* (EASA, 2015).

Drones can vary in size, speed, endurance and take-off weight (EC, 2014). They can either be a form of airplane with fixed wings or use a tilt rotor system, like a helicopter, that lifts and propels (Nentwich & Horváth, 2018a). Drones can be piloted remotely by an operator. Only those flying automatically without any kind of human intervention in their flight management are considered autonomous. The ability to operate in autonomous mode, without an individual pilot needed for each drone, is essential for drone use in delivery services (Nentwich & Horváth, 2018a). Autonomous flying requires a drone to be equipped with an autopilot, while the route of the drone will be determined by the input (path-planning algorithm) from the user. Other software components are also included. Geolocation devices, such as GPS, are used to determine drone location, while the inertial measurement unit (IMU) communicates other sensor data collected during the flight and enables the autopilot to adjust the flight accordingly. To facilitate navigation, the drone is equipped with a camera(s) or radar. Emergency remote control enables an operator to activate manual operation of the drone at any time (Brunner *et al.*, 2018; Krishna *et al.*, 2016).

Drone technology is evolving at a fast pace with the increasing potential to successfully compete with more ‘traditional’ technological alternatives in a variety of civil industries. Considerable technological progress has allowed for their mass production and commercial application in areas additional to retail and delivery, namely research, mapping, monitoring, leisure, tourism, cultural heritage, nature conservation, agriculture, photography, emergency response, and so on, leading to an exponential increase in drone markets composed of both manufacturers and service providers (Santamarina-Campos, 2018). Approximately 2.2 million drones for personal and commercial use were sold in 2016 worldwide, and the drone world market is expected to be worth more than US\$11.2 billion by 2020 (Forni & Muelen, 2017). In Europe alone the estimated number of commercial drones operating in 2016 was that of 10,000 units, along with 1–1.5 million customer drone units (e.g. drones used for leisure) (SESAR Joint Undertaking, 2016). Further growth is expected, as their number in Europe is forecasted to reach 200,000 units by 2025 and 395,000 units by 2035 (SESAR Joint Undertaking, 2016). According to Molina & Oña (2018), based on statistics from Tractica (2017), the revenue from commercial drones in Europe amounted to US\$99.53 million in 2015 and is forecasted to reach US\$3035.33 million by 2025. Available, albeit insufficiently comprehensive, data suggests that a significant number of drone manufacturers are

located in the UK, Italy, Germany and France, while a significant number of drone operators can be found in the UK, Spain, France and Italy (Molina & Oña, 2018).

Several companies use or have already tested drones for delivery services. Alongside smaller enterprises that are already employing drones for delivery, such as *Zipline International* (Markoff, 2016), drones are also being tested by large multinational companies including Amazon, DHL and Google (Nentwich & Horváth, 2018a). Amazon launched its Prime Air delivery in Cambridge, UK, in 2016 (Amazon, 2016). It announced further investment in the research and development (R&D) of technology used in drones for shipping (Kang, 2016), and indicated that its aerial delivery could be available as soon as 2019–2020 (Heathman, 2018). The Austrian Post tested drone delivery of packages weighing up to 3.5kg in 2017 (Nentwich & Horváth, 2018a) and DHL concluded a pilot project using parcel drones for the delivery of medicine to remote areas in 2018 (Deutsche Post DHL Group, 2018). All in all, growing interest in drones in Europe and worldwide attracts further investment in their R&D.

Research efforts focus on the development of solid sense and avoid technology, which is essential for autonomous drones to operate safely and without collision (Nentwich & Horváth, 2018a). Investments in the research of autonomy and the artificial intelligence of drones are also regarded as a priority by the EU in the context of developing a fully operational framework named U-Space, which would enable secure drone management (Ministerie Van Infrastructuur en Waterstaat & EASA, 2018). Other areas of research include: cargo transport and release technology, energy efficiency, noise pollution, safety and security (Brunner *et al.*, 2018).

#### Overall impact

The steady increase in the number of drones worldwide indicates that they are having a considerable influence on all areas, including economic, social, environmental and legal domains. The total number of commercial drones in Europe is expected to reach 395,000 units by 2035. Delivery drones, with an estimated 70,000 units, are second only to the 150,000 units foreseen for agriculture, surpassing the 60,000 units estimated for public safety and security and the 10,000 units used in the energy sector (SESAR Joint Undertaking, 2016). Drones for delivery remain attractive to manufacturers (Molina & Oña, 2018) because they have the greatest potential for future growth in the longer term (Doole *et al.*, 2018; EC, 2014; SESAR Joint Undertaking, 2016). They are at the forefront of the shipping, transport and logistics industry's effort to overcome common problems

with terrestrial transportation (ageing infrastructure, congestion, emissions) (Manjoo, 2016) and find a cost-effective solution to last-mile delivery (Doole *et al.*, 2018). The EC (2019b) estimates that the drone industry will have a considerable positive economic effect of approximately €10 billion per annum, mainly in services, and that it will create approximately 100,000 new jobs across Europe in the next 20 years. However, the automation of shipping, through drone employment for last-mile delivery, poses a risk to job security in unskilled labour (Nentwich & Horváth, 2018a).

The employment of drones also raises many issues surrounding public health, safety and security as well as privacy. The very obvious legal implication of using drones for delivery is the need for common EU regulation for the operation of drones in autonomous mode (without a pilot), flying over urban, private or protected areas, or in relation to cross-country-border traffic. Existing regulation allows commercial delivery drones to operate only on a case-by-case basis (Nentwich & Horváth, 2018b). Security and safety issues are linked to the risk of drone collision with manned aircraft and to the potential harm caused to people or the damage suffered by property (EASA, 2015). Drones with malfunctioning navigation or those impaired by weather conditions could cause serious injuries, loss of life, and considerable destruction of material assets. Overall harm could be further exacerbated if drone cargo, particularly if heavy or dangerous, consequently falls on urban or populated areas (Nentwich & Horváth, 2018b). There are further security issues surrounding the use of delivery drones for illicit purposes, such as smuggling, transportation of drugs or weapons, or even terrorist attacks (Nentwich & Horváth, 2018a). The serious nature of this problem was highlighted by the disruption caused by a drone sighting at Gatwick Airport, UK, in December 2018. It resulted in the prompt instalment of anti-drone equipment at airports across the UK (BBC, 2019).

Privacy concerns are related to a drone's ability to record and transmit data in real time (EASA, 2015). Data generated and stored during flight and delivery could be linked to specific people, or could reveal sensitive details of private properties and public buildings (Nentwich & Horváth, 2018a). Drones for delivery are equipped with cameras that enable their orientation within the space that surrounds them. They also produce audiovisual material that could potentially be required by law to be stored as evidence that no damage was caused by a drone during its operation. An enormous amount of data collected by drones in this way, especially in combination with other sources, could help to build a complete profile of an individual or area and, thus, provide sensitive information that could be misused by third parties in the worst case (Nentwich & Horváth, 2018b).

Thus, Rice (2019) concludes that there is a chance that the further proliferation in drone numbers in the near future may increase privacy concerns amongst the general public and private companies alike.

Further unease is related to ethical issues such as the question of ethical decisions made by pre-programmed algorithms. Autonomous drones, much like other autonomous vehicles, might need to make an ethical decision, such as where to crash, whom to injure or what damage to cause, in situations in which harm cannot be prevented. As these decisions need to be made and programmed in advance, the question remains as to who will decide and how the implementation of such decisions will be overseen (Nentwich & Horváth, 2018a).

#### Impacts on the European environment

There are pros and cons in respect of employing drones for delivery from the environmental perspective. The main benefit for the European environment is that, compared to traditional (fossil-fuel-based) methods of delivery, delivery drones can help to conserve energy and reduce CO<sub>2</sub> emissions, whereby assisting the EU in achieving its key climate targets. Several comparative studies (Figliozzi, 2017; Goldchild & Toy, 2017; Park *et al.*, 2018; Stolaroff *et al.*, 2018) demonstrate that delivery drones are considerably more CO<sub>2</sub>-efficient than conventional means of transportation, with the amount of CO<sub>2</sub> emissions being greatly reduced, but still depending on other specific factors involved.

Delivery drones perform better than:

- conventional delivery trucks, producing considerably less CO<sub>2</sub> emission when the distance travelled is short, energy requirements are low and the number of recipients is small (Goldchild & Toy, 2017);
- diesel vans, with significantly better results when the payloads are small and customers are clustered around one delivery route (Figliozzi, 2017);
- motorcycles, with higher CO<sub>2</sub> efficiency achieved in rural than in urban environments (Park *et al.*, 2018).

However, Stolaroff *et al.* (2018) point out that emissions related to extra warehousing, as required by a drone-based logistics system, might reduce, if not hinder, the overall positive environmental impact. Thus, attainment of the desired emissions reduction would depend greatly on finding solutions regarding how to diminish the negative impact of extra warehousing, decrease the size of drones (Stolaroff *et al.*, 2018) and continuously increase the use of renewable sources of energy used for drone operation, such as solar and wind power (Park *et al.*, 2018). The life cycle of batteries used by drones also needs to be considered (Nentwich & Horváth, 2018a). Above all, comprehensive assessment of delivery drones' environmental impact — in relation to their energy consumption and CO<sub>2</sub> emissions production — is still pending.

Amongst the significant negative effects that need to be seriously considered is the threat to wildlife, especially birds, as a result of collision, noise or stress caused by the frequent presence of drones in their habitat. Operating at a low altitude, usually below 500m, means that drones are likely to come into contact with wild animals (Mulero-Pázmány *et al.*, 2017). Yet, the consequences of undue stress caused by drones to wildlife have not been systematically studied and are little understood. It has been suggested that animals constantly bothered by drones might use up their finite energy reserves for self-defence, or might start responding incorrectly to other threats as a consequence of exposure to drones (Greenwood, 2018). Moreover, drones can have a detrimental impact on an animal's reproduction and survival (Hodgson & Koh, 2016; Mayntz, 2018; Mulero-Pázmány *et al.*, 2017). The evidence of bird–drone interaction, such as two eagles mistaking a drone for food in Austria (Staufenberg, 2015), is growing. Warnings have been released to inform drone operators about the possibility of drones being perceived as a threat by wild animals (The Local, 2018). In some areas, such as parks in London, drones have been banned from operating due to concerns related to their negative influence on wildlife (Peyer, 2015). This suggests that fears related to drone impact on wildlife will increase with the growing number of drones operating in European skies.

Furthermore, noise and aesthetic pollution can have a negative impact on humans living close to future delivery air corridors. Noise-sensitive individuals in particular could be disturbed by the noise produced by a drone as it moves its cargo close or near to them. This might result in resistance in the population to drones. Other potential environmental risks include the debris resulting from collisions and dropped cargo and the related responsibility for the disposal of such debris (Nentwich & Horváth, 2018a).

### Implications for environmental policy in Europe

Under current EU legislation (Regulation 2018/1139), which was adopted jointly by the European Parliament and the Council on 4 July 2018 (European Parliament and the Council, 2018), drones of all categories fall under the regulation of EASA, which works to provide a common regulatory framework. However, as with other fast-developing technologies, existing legislation lags behind the technological development. This applies to the environmental implications of drones used for the shipping of goods, too. A new regulatory framework, under development by EASA, also intends to address the concerns related to environmental protection, amongst other issues, proposing detailed checks on the noise emissions of drones during a conformity assessment (EASA, 2018). It aims to harmonise heterogeneous legislation amongst member states and the EU, and introduce common technical requirements for the mass-produced category of drones, while leaving the member states flexibility to create zones in which flying drones will be permitted, restricted or prohibited.

Areas in need of future EU legislation from an environmental perspective might include the common regulation of the technical parameters of delivery drones that would promote more sustainable design and operation. They might also include environmentally friendly logistics systems for drone deliveries influenced by the need to protect natural habitats, animals and humans from drone-related negative impacts. What is more, as Nentwich & Horváth (2018a) point out, the introduction of drone delivery services in the EU would require common rules for drone traffic.

## **IV.IV Off-grid electricity**

### Description

Although off-grid solutions have been traditionally designed for countries in the Global South, the number of households going off-grid in the Global North seems to be increasing (IRENA, 2015). While for the first, off-grid electricity is often the only means by which to provide and maintain energy access in underdeveloped remote areas or for underprivileged low-income households, in the second it is individual or collective decisions which are not always driven by financial calculations (Skea *et al.*, 2011). Off-grid electricity is therefore a rather complex mix of different approaches, technologies and solutions. In analysing this signal, we need to work with different archetypes of the off-grid situations in Europe. We set forth two basics:



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- off-grid as a high-tech approach, which uses advanced real estate technologies as well as systems that are controlled by information technology (IT), backed up by high-capacity batteries;
  - off-grid as a low-tech approach, which is based on simple and low-cost solutions, and often using technologies and approaches originally designed for the Global South countries.

While more comprehensive information is missing, available information indicates that off-grid solutions are gaining in popularity. According to the International Renewable Energy Agency (IRENA, 2015), almost 26 million households (approximately 100 million people) are served through off-grid renewable energy systems globally, including: 20 million households through solar home systems, 5 million through renewables-based minigrids, and 0.8 million through small wind turbines. What is more, the global renewable energy off-grid capacity increased 3.5 times from 1909.684MW in 2008 to 6574.595MW in 2017 (IRENA, 2018a). This is related to recent advancements in R&D yielding various technological solutions based on renewable energy. Expanding the production of renewable technologies, solar panels, high-efficiency solar technology, and long-lasting batteries leads to an economy of scale effect that decreases the relative price of the materials and equipment required for off-grid solutions. IT evolution supports demand-side management and improves energy efficiency, further decreasing investment and operational costs (Metz *et al.*, 2000). Such synergy amongst R&D, the growing production capacity and the push for more energy efficiency seems to be at the bottom of the off-grid worldwide advance.

Off-grid technology application varies around the world. In the Global South, it is a solution for providing and maintaining energy access in poorer areas and households, or for people who are too far from the grid. While cheaper technologies are commonplace, the most widespread are solar panels (IRENA, 2018). In the Global North, off-grid systems consist of two types: minigrids for rural communities and for institutional, commercial and industrial constructions and buildings, and the self-consumption of solar photovoltaic power generation in residential households (IRENA, 2015). High-tech and low-tech off-grid approaches can be distinguished. The first is a combination of lifestyle decisions and economic considerations. Life quality is meant to be maintained, while electricity needs are addressed through a combination of demand-side management (energy auditing, efficiency improvement, IT), encouraging consumers to optimise their energy use (Metz *et al.*, 2000). Electricity is generated by using solar, wind or geothermal systems combined with batteries for electrical storage and supplying electrical current for use by appliances (e.g. light, computer, stove, and so on) (IRENA, 2018). Equally, off-grid, as a low-tech approach, could also

be contemplated as an alternative lifestyle and/or an economic decision. Moreover, in some cases, it might be amongst the essentials of disadvantaged households. Thus, people might go off-grid because of their intention to decrease their ecological footprint, live simpler lives or disconnect from corporations. They usually focus on simple technologies ('small is beautiful'), alternative housing stock, and solar panels. Others might invest in off-grid technologies while seeking to benefit from the increased value of the property or from preventing the uncertainty surrounding the volatile electricity market. In short, behind people's long-term decisions to go off-grid may be a strong economic rationale that is difficult to distinguish from environmental concerns.

Last but not least, debt or illegal dwelling status might obstruct some people from being connected to the mains. Consequently, they might be dependent on more controversial sources of electricity, such as diesel generators. The substantial nature of these issues is underlined by the 50 million EU inhabitants estimated to suffer from 'energy poverty' and who struggle to heat their homes and pay utility bills on time (Thomson & Bouzarovski, 2018). SDGs and the Reflection Paper Towards a Sustainable Europe by 2030 (EC, 2019c) provide a robust framework for policies and approaches linking energy and social policies.

#### Overall impact

Overall impact in the European context is strongly affiliated with off-grid electricity generated by individual households and communities. The growing number of off-grid users seems to indicate that electric energy could, for a reasonable price, be generated by a combination of high- and low-tech solutions (excluding experimental technologies). Yet, available information (IRENA, 2018) regarding the patterns of individual households' investment in renewable energy sources and the increasing self-generation of electricity shows that only a small minority of these households are completely disconnected from the grid. To be completely off-grid requires substantial investment. SonnenBatterie (2018), in its study for Germany, concludes that batteries combined with a photovoltaic system could help users to meet approximately 75% of their annual energy needs with self-produced and clean energy, while it remains cheaper to cover the remaining 25% with an outside source. In comparison, the Rocky Mountain Institute (2014), based on its HOMER software program experiment, argues that going off-grid with renewables based on solar photovoltaic will be economically more advantageous than staying connected to the grid. Independent of the ongoing research, off-grid villages and installations are springing up in locations as diverse as Denmark, Japan, the USA and Australia. For instance, in Denmark, 270 inhabitants established the first off-

grid village in the country called ‘Fertile Soils’ with the purpose of producing their own heat and electricity (State of Green, 2018). Above all, self-sustained settlements, if properly managed, could have a positive environmental impact. By sharing investments, equipment and batteries, they may optimise costs and better address problems of system efficiency or recycling.

Ultimately, the social dimension of the approach should not be neglected. As Rosen (2010) points out, off-grid systems have the potential to assist in bringing life back to the countryside negatively affected by the declining population trend. What is more, off-grid solutions overlap with approaches outlined in the EU framework for rural development programmes (EC, 2019d).

#### Impact on the European environment

Off-grid electricity systems based on renewables are subject to the same concerns as those of the renewable industry. Regardless of the degree of household self-sufficiency (50%, 75% or 100%), the examination of their environmental impact should be carried out in a comprehensive way, from the cradle to the grave, and should consider all of the materials, equipment, batteries, etc. used for their production, maintenance and disposal. The main issue surrounding off-grid pertains to the unavoidable and extensive use of batteries. Despite their rapid development, a question remains as to how to deal with their end-of-life problem, i.e. reuse versus dismantling and recycling (EEA, 2018a). Thus, the State of California encourages solar and wind power generation to be connected to the electrical grid, with additional equipment, such as charge controllers, being required (CEC, 2019). Yet, smaller batteries needed for individual off-grid installations, including mobile batteries for e-vehicles, may still prove to be more environmentally friendly than potentially in future manufactured large-scale static batteries providing backup to numerous households (EEA, 2018a). However, concerns related to the use of batteries might form part of a wider solution including battery electric vehicles (BEVs). Ongoing research on BEV batteries is centred on the electricity grid, the storing of excess renewable power and providing grid-stabilising services, either while BEVs are plugged in or as a second-life use of the batteries (EEA, 2018b).

#### Implications for environmental policy in Europe

Off-grid solutions, especially for villages, communities and remote facilities, may prove to be a more environmentally and economically sounder alternative. It may build on a desire and readiness by a proportion of the population to have a less energy-intensive and a sustainable lifestyle. It also

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raises the question of whether it is plausible to invest in centralised technical energy or water infrastructure in areas with a decreasing population and/or low purchasing power. Thus, the EU could consider how to promote economically, socially and environmentally sound alternatives to central grids, using tools of economic and social cohesion policies and by providing guidance to the member states on schemes and incentives on the national level.

Energy production and consumption is unavoidably a social problem. Growing economic inequalities, changing demographic patterns, and the depopulation of rural areas, as well as increasing environmental awareness, point to the need to merge energy policies with social interventions in accordance with SDGs and, in particular, the goal of affordable and clean energy.

All in all, the above-presented off-grid analysis makes a strong case for the further strengthening of environmental regulations and incentives for the renewable energy sector. Research should continue and be supported by the EU in respect of energy storage solutions, environmental management of excess renewable power, and grid-stabilising services. Additionally, attention needs to be paid to BEV options and the development of recycling schemes for equipment and materials in accordance with the promoted principles of a circular economy.

## V. Discussion

Artificial meat, blockchain, delivery drones and off-grid electricity were identified by FLIS as being emerging issues. They represent new technological advancements with the potential to play an important role in the transition to a global low-carbon economy. To examine their advent a variety of academic and non-academic publications, including outliers, such as blogs and websites, were explored. The purpose of such an approach is to challenge and distort the conventional view on the future and, thus, stimulate the creation of its alternatives (Inayatullah, 2013). Drawing on the triadic concept of the weak signal as proposed by Hiltunen (2008)<sup>1</sup>, it is to interpret or make sense of the emerging signal in relation to its future. Yet, while the patterns of the process of the emergence of new technologies were analysed, the elaboration of alternative futures was purposefully excluded so as to be addressed by a later inquiry.

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<sup>1</sup> The triadic model of weak signals is based on three dimensions: *representamen*, or a form of the signal; *object*, or the emerging issue that the signal indicates; and *interpretant*, or making sense of the signal regarding its future. Here, a weak signal is called ‘future sign’ (Hiltunen, 2007, 2008).

Several threats and opportunities were identified in relation to each of the analysed emerging issues. The transition to artificial meat production could greatly benefit the global and European natural environment by reducing the total GHG emissions, decreasing pressure on finite natural resources and improving ecosystem protection. However, appropriate policies designed to guarantee the conformity of the whole production process to principles of sustainability would be imperative in order to achieve the desired outcome. Similarly, regulations addressing the excessive use of power and energy would be required to reap the full environmental benefits of blockchain. Its enhanced transparency of transactions and increased efficiency of recordkeeping could be employed to apply the sustainability criteria on complex organising activities, such as the supply chain. To ensure that a wider application of drones for delivery results in less energy being consumed and less CO<sub>2</sub> emission being produced, future policies need to aim towards achieving more sustainable design and more environmentally friendly logistics. An important increase in energy efficiency and reduced CO<sub>2</sub> emissions are the main rewards related to off-grid electricity generated from renewable resources. However, policies governing the off-grid solutions need to encourage and support innovative solutions for issues, such as material and equipment recycling or the management and storage of excess power produced. Above all, this also demonstrates that the processes through which the analysed issues are emerging are far from being straightforward.

Tracking down information on artificial meat, blockchain, drones for delivery, and off-grid electricity shows that they are fast-emerging issues. They have great potential to deliver environmental benefits and their quick dissemination might assist in averting the looming environmental crises, mainly by reducing the total GHG emissions, increasing energy efficiency, alleviating pressure on Earth's finite natural resources and advancing protection of the ecosystem. However, the complexity and the wide array of risks related to their more extensive application challenge the environmental discourse, also called 'Promethean responses' (McGrail, 2011), whose adherents believe that new technological advancements are the only remedy for global environmental problems and that the currently dominant neoliberal economic model is unproblematic. Consequently, this helps to distort the dominant worldview based on neoliberal ideology and market logic and create stimuli for policymakers to think in novel ways regarding the future application of here-discussed new technologies. They could provide viable solutions only if the threats and risks related to their wider spread are thoroughly addressed by policies that are adequate and adopted in a timely manner. To reiterate the argument put forward by the EEA (2013),

a comprehensive understanding of all consequences for the natural and social worlds is essential before further diffusion of these new technologies. As existing legislation commonly lags behind the technological development, further research on these technologies is of the utmost importance.

## **VI. Conclusions**

Human activity is causing irreversible damage to the natural environment and we must begin to act now in order to prevent the worst impact on our planet. Although technological innovations promise to introduce solutions that might help us to overcome the multifaceted environmental catastrophe on the horizon, caution must be exercised when considering their widespread application without a comprehensive understanding of their full implications for society and the environment. The emergence of new technologies is a highly complex process and extensive research is required in order to ensure the timely adoption of adequate policies prior to the diffusion of such technology. Such policies should centre on environmental and social issues instead of being narrowly market-focused.

Future studies and forward-looking assessments of technological innovations are indispensable in this regard. They are essential tools in the hands of policymakers. Knowledge produced through careful examination of new technologies as weak signals and emerging issues can increase the awareness of decision makers in respect of the possible threats and opportunities. Preparedness for a variety of alternative futures enhances the resilience of policymaking and can assist our society and communities in better responding to possible dramatic changes that we are about to experience in the future. All of this is ever more important, as humanity has already begun to walk the path with respect to facing the unpredictable and unforeseeable consequences of global environmental crises, such as climate emergency or fast-paced wildlife extinction.

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