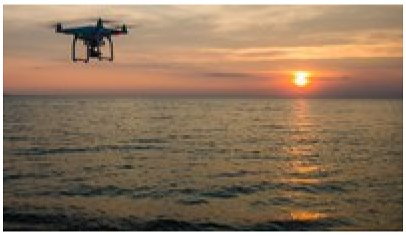
Drivers of change

Delivery drones and the environment



A technology with uncertain potential for reducing greenhouse gas emissions from e-commerce and the logistics industry and concerns over increased noise pollution and threats to wildlife.

Drones, originally developed and used for military purposes, have found applications in many civil sector areas during the last decade. Although often referred to as 'remotely piloted aircraft systems' or 'unmanned aircraft/vehicles/systems', drones are commonly defined simply as flying objects or 'robots' with no pilot on board (Santamarina Campos, 2018). The European Aviation Safety Agency (EASA) defines a drone as:

> 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 take the form of either an aeroplane with fixed wings or a helicopter using a tilt rotor system (Nentwich and Horváth, 2018a). Drones can be piloted remotely by an operator or fly automatically without any kind of human intervention. The autonomous mode is essential for delivery drones, as an individual pilot behind each drone would be too costly (Nentwich and Horváth, 2018a). Emergency remote control enables an operator to activate manual operation of the drone at any time (Krishna et al., 2016; Brunner et al.,2018).

Drone technology is evolving at a very fast pace and has increasing potential to compete successfully with more traditional alternatives in a number of sectors beyond retail and delivery. Such sectors include research, observation and monitoring, nature conservation, agriculture, emergency response for humanitarian action and civil protection, leisure, competitive sports, tourism and cultural heritage, cinema and photography. This potential is reflected in the exponential growth of drone-related markets recently, benefiting both manufacturers and service providers (Santamarina Campos, 2018). In 2016, approximately 2.2 million drones were sold for personal and commercial use worldwide (Gartner, 2017). Some specialised analysts consider that the global drone market could grow from USD 14 billion in 2018 to USD 43 billion in 2024 (Drone Industry Insights, 2019).

At present, the sale of customer drones (for personal use) is much higher than that of commercial drones, which include delivery drones. In Europe, the estimated number of commercial drones operating in 2016 was 10 000 units, compared with 1-1.5 million consumer drone units (SESAR, 2016). **The number of commercial drones is forecast to rise rapidly**, however, reaching projected sales in Europe of 200 000 units in 2025 and 395 000 units in 2035 (SESAR, 2016). Of the latter figure, 150 000 units are expected to be used in agriculture, 70 000 for delivery, 60 000 for public safety and security, 10 000 in the energy sector and 100 000 units in other growth sectors, such as media and mining and construction (SESAR, 2016). Drones for delivery are attractive to manufacturers (Molina and Oña, 2018) as they have very substantial potential for long-term growth (EC, 2014; SESAR, 2016; Doole et al.,2018).

The forecast growth in delivery drone fleets is based in part on the strong interest expressed by large multinational companies such as Amazon, DHL and Google. Delivery drones are already in use today by small enterprises such as Zipline International (for the delivery of medical products in Africa). In 2016, Amazon experimentally launched its Prime Air delivery service in the United Kingdom (Amazon, 2016). Austria's postal service tested drone delivery of packages up to 3.5 kg in 2017 (Nentwich and Horváth, 2018a). DHL concluded a pilot project using parcel drones to deliver medicine to remote areas in 2018 (Deutsche Post DHL Group, 2018).

Overall, **investments in research and development are growing**. Many research efforts focus on the development of sense and avoid technology, which is essential for autonomous drones to operate safely and without collision (Nentwich and Horváth, 2018a). The EU is also prioritising investments in artificial intelligence to enable complex drone operations with a high degree of automation and security (IenW and EASA, 2018). Other areas of research include cargo transport and release technology, energy efficiency, noise pollution, safety and security (Brunner et al., 2018).

Overall implications (non-environmental)

The expected increase in the use of delivery drones is likely to have significant economic, social and legal implications. The shipping, transport and logistics industries increasingly see delivery drones as a means to overcome shared problems relating to terrestrial transport (such as an ageing infrastructure, congestion, greenhouse gas (GHG) emissions and air pollutants), and a cost-effective solution to last-mile delivery (Manjoo, 2016; Doole et al.,2018). The European Commission estimates that the drone industry will have a considerable positive effect on the economy, valued at about EUR 10 billion per year, and will create approximately 100 000 new jobs in the next 20 years (EC, 2019a). However, delivery drones also pose a risk to unskilled job security (Nentwich and Horváth, 2018a).

From a societal and legal perspective, the use of delivery drones raises many issues relating to safety, security, privacy and ethics. Key safety and security issues relate to the risk of collision with other drones or manned aircraft and crashes due to malfunctioning navigation or bad weather conditions. All these could result in serious harm to people and damage to property (EASA, 2015), which would be further exacerbated if the drone cargo is heavy or dangerous, or they are flying in urban or populated areas (Nentwich and Horváth, 2018b). Other security issues relate to the use of delivery drones for illicit purposes, such as smuggling, transport of drugs or weapons, or even terrorist attacks (Nentwich and Horváth, 2018b). In recent years, anti-nuclear activists have piloted drone flights over nuclear plants in France to demonstrate potential risks, while drone sightings at Gatwick Airport have caused major disruption (Le Monde, 2018; BBC, 2019).

Privacy concerns relate 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 associated with specific individuals and reveal sensitive details of private properties and public buildings (Nentwich and Horváth, 2018a). Indeed, delivery drones are equipped with cameras enabling their spatial orientation, and they also produce audio-visual material that could potentially be required by law to be stored as evidence that no damage was caused by a drone during operation. Therefore, the enormous amount of data collected by drones could help to build, especially when combined with other sources of information, a complete profile of an individual, property or area and thus provide sensitive information that could be misused by third parties (Nentwich and Horváth, 2018b). Further proliferation of drone numbers in the near future may increase privacy concerns among the general public and private companies (Rice, 2019).

Similarly to other digitally enabled technologies (e.g. self-driving cars), ethical issues also exist due to the use of algorithms. Autonomous drones might need to 'make' an ethical decision in situations where harm cannot be prevented because of an incident, such as where to crash, who to injure and what damage to cause. As the algorithm for these decisions need to be programmed in advance, the question remains who will decide and how the implementation of such decisions will be overseen (Nentwich and Horváth, 2018a).

Implications for the European environment

From an environmental perspective, there are pros and cons to using drones for delivery services. The main expected benefit for the environment is that, compared with many traditional methods of delivery (motorcycles, cars, vans, lorries and planes using fossil fuel), drones could reduce

CO_2 emissions as well as other air pollutants for that sector. Several comparative studies (Figliozzi, 2017; Goldchild and Toy, 2017; Park et al., 2018; Stolaroff et al., 2018) show that delivery drones are more 'CO_2-efficient' than conventional means of transport, with the amount of CO_2 emissions being greatly reduced, but this depends on a number of specific factors. In short, these studies show that delivery drones can perform better than:

- conventional delivery trucks, as they produce considerably less CO_2 emissions when the distance travelled is short, energy requirements are low and number of recipients is small (Goldchild and 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_2 efficiency achieved in rural than in urban environments (Park et al., 2018).

These results should, however, be viewed with caution. They focus on a narrow market, i.e. last-mile delivery to a single or few recipients with low payload. It is also unclear whether drone delivery will simply replace alternative delivery methods or lead to additional delivery trips. Given the expected timeline for commercial large-scale drone deliveries, electromobility will probably also be mainstream in land transport, meaning that the comparison should be made with electric vehicles, rather than conventional petrol or diesel ones.

These studies also do not consider broader systemic effects along the entire logistics chain. For instance, even if the environmental impacts from direct emissions are reduced, emissions relating to extra warehousing, required by a drone-based logistics system, may reduce or eliminate the benefits (Stolaroff et al., 2018). Therefore, reductions in emissions will depend on finding ways to diminish the negative impact of extra warehousing, decrease the size of drones (Stolaroff et al.,2018) and continuously increase the use of renewable energy sources, such as solar and wind power, for drone operation (Park et al., 2018). In addition, as for many other technologies, the life cycle of batteries needs to be factored in (Nentwich and Horváth, 2018a). At present, the absence of comprehensive assessments of the environmental impact of delivery drones prevents robust conclusions about GHGs and air pollutants.

Among significant negative environmental effects, the threat to wildlife, especially birds, is a key concern. Operating at low altitude, usually below 500 metres, drones are likely to come into contact with wild animals (Mulero-Pázmány et al., 2017). Beyond the obvious risk of collision, birds could be affected by the noise and stress caused by the frequent presence of drones in their habitat. To date, the consequences of undue stress caused by drones to wildlife have not been studied systematically and are little understood. Animals constantly bothered by drones might use up their finite energy reserves for self-defence or might start responding incorrectly to other threats (Greenwood, 2018).

Drones can also have a detrimental impact on an animal's reproduction and survival (Mayntz, 2018; Mulero-Pázmány et al., 2017). Existing studies suggest that the essence and intensity of impact will depend on a variety of factors, including the type of drone and its method of operation, the species of animal and many other contextual factors, such as habitat, season and life-stage (Hodgson and Koh, 2016; Mulero-Pázmány et al., 2017). Bird species, animals in larger groups (more than 30 individuals) and animals in the non-breeding stage of their reproductive cycles were found to be more sensitive to disturbances relating to the presence of drones (Mulero-Pázmány et al., 2017). Evidence is growing of bird-drone interaction, such as two eagles mistaking a drone for food in Austria (Staufenberg, 2015). 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, authorities have banned drones from operating because of concerns over their negative influence on wildlife (Peyer, 2015).

Other potential environmental implications include noise pollution, which can lead to discomfort and more serious health impacts on humans living close to delivery air corridors, and negative visual impacts on urban environments. Both factors might also result in resistance from society to the mainstreaming of delivery drones. Other potential environmental risks include the debris resulting from collisions and dropped cargo and the related responsibility for their disposal (Nentwich and Horváth, 2018a).

Implications for environmental policy in Europe

Following the entry into force of the new EU Aviation Safety Regulation 2018/1139 (‘EASA Regulation’), the European Commission is responsible for setting rules for unmanned aircraft, irrespective of their weight (EU, 2018; EC, 2019b). In 2019, the European Commission adopted two new regulations on unmanned aircraft systems and on rules and procedures for the operation of unmanned aircraft (EU, 2019a; 2019b). Building on existing national rules and providing a now harmonised framework across the EU, the ambition is to ‘pave the way for safe, secure and green operations’ (EC, 2019c).

As regards environmental protection, the EASA Regulation stresses that drones ‘must be designed’ to minimise noise and emissions ‘as far as possible’ (EU, 2018). Aircraft need to ‘comply with … environmental protection requirements’ and to ‘be issued with a certificate of airworthiness’ (EU, 2018). When taking measures to address emissions and noise, EASA ‘shall aim to prevent significant harmful effects on climate, environment and human health’ (EU, 2018). However, there is no explicit mention of environmental considerations relating to threats to wildlife or promoting the more sustainable design and operation of drones throughout their life cycle. Therefore, common EU rules and specifications could be established regarding topics such as environmentally friendly logistics and operation systems for delivery drones to minimise impacts on wildlife and foster sustainability.

The EASA Regulation invites all relevant EU institutions and the Member States to ‘cooperate on environmental matters … with a view to ensuring that interdependencies between climate and environmental protection, human health and other, technical, domains of civil aviation are taken into account' (EU, 2018). EASA should also 'assist the Commission with the definition and coordination of civil aviation environmental protection policies and actions' and 'at least every three years, publish an environmental review' that builds on available information (EU, 2018). The EEA has already contributed to the two first European aviation environmental reports, published in 2016 and 2019. The 2019 edition mentioned drones and stressed that 'an in-depth life cycle analysis will be required to assess the environmental impacts of [drones] in comparison to conventional aircraft' (EASA, 2019).

This brief belongs to a series of 'rapid assessments' on the implications of emerging trends for the environment and environmental policies in Europe. The identification of the topic results from a participatory horizon-scanning process run by experts from the Eionet National Reference Centres on Forward Looking Information and Services (NRC FLIS) during the period 2018-2019. The brief was drafted with support from the European Environment Agency (EEA) and the European Topic Centre on Waste Materials and the Green Economy (ETC WMGE). It is conceived as a living document that should be enriched through interactions with other knowledge communities and stakeholders, and evolve according to technological developments.

Type of signal: **Emerging trend**

Geographical scope: **Local, regional, national, European, global**

Origin of signal: **Technological**

Time horizon of expected significant impact: **Mid- to long-term**

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Main related EU policies

- Environment action programme to 2030
- 2030 Climate and energy framework
- European strategy for low-emission mobility
- Environmental Noise Directive
- Clean air programme for Europe
- Ambient Air Quality and National Emission Ceilings Directives

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