

Marianne Harbo Frederiksen, Otilia-Ana Vrincianu Mouridsen & Mette Præst Knudsen

Drones for inspection of infrastructure: Barriers, opportunities and successful uses

June 2019

Colophon

This memo brings into focus a range of opportunities and challenges in using unmanned aerial vehicles, also known as drones, for inspection of infrastructure in Denmark. The authors thank The Danish Industry Foundation for the financial support for the research behind the memo that was conducted as part of the project “Innovation on Wings”. The authors also thank the participating companies and interviewees for their contributions. Nevertheless, all mistakes or misunderstandings are the sole responsibility of the authors.



Authors

Marianne Harbo Frederiksen: Associate Professor at SDU Innovation and Design Engineering, Department of Technology and Innovation, University of Southern Denmark.

Contact: mha@iti.sdu.dk or website: <http://findresearcher.sdu.dk:8080/portal/da/person/mhf>

Marianne Harbo Frederiksen focuses her research on activities related to new product design, development, and innovation, ranging from managing ideas at the front end of the innovation process towards achieving successful commercialization based on the adoption by users and customers of new technologies. Currently, she analyzes the development of the Danish drone innovation ecosystem and advises actors of the industry.

Otilia-Ana Vrincianu Mouridsen: Former Research Assistant at the University of Southern Denmark.

She is kindly acknowledged for her participation and contributions to this memo.

Mette Præst Knudsen: Professor and Head of the Center for Integrative Innovation Management, Department of Marketing & Management, University of Southern Denmark.

Contact: mpk@sam.sdu.dk or website: <http://findresearcher.sdu.dk:8080/portal/da/person/mpk>

The research of Mette Præst Knudsen seeks to integrate market, management, and technological perspectives on innovation processes. The focus on commercialization is particularly useful in relation to the development of new technologies with unknown market potential as for instance with innovative drone technologies and green technologies. The most recent projects are concerned with analyzing the effects of the latest transformative technologies and how they influence work and innovation – like industry 4.0, technological platforms, and additive manufacturing.

Contents

1	General introduction	3
2	Why focus on drone applications?	4
3	Using drones for inspection of infrastructure	6
3.1	Inspection of road infrastructure	6
3.2	Inspection of railroad infrastructure.....	9
3.3	Inspection of electricity infrastructure.....	10
3.3.1	In-depth case no. 1: Drones for inspection of many kilometers of power lines	
3.4	Inspection of heating infrastructure.....	13
3.4.1	In-depth case no. 2: Mapping of Copenhagen’s heating pipeline network	
4	Barriers and opportunities	17
5	Methods	19

1 General introduction

This is the second memo in a series of publications that focus on the opportunities and challenges in using unmanned aerial vehicles, also known as drones, for civil and commercial applications in Denmark. The aim of the publications is to inform existing and potential new businesses, inventors, investors, and policy makers about the opportunities for drones to develop into a new growth industry.

The series of publications are concerned with the following fields of application:

1. Drones for offshore and maritime missions: Opportunities and barriers
https://www.sdu.dk/en/om_sdu/institutter_centre/i_marketing/marketing_nyheder/free+the+drones
2. Drones for inspection of infrastructure: Barriers, opportunities and successful uses (this memo)
3. Drones for the health sector and emergency management (upcoming publication).

This memo no. 2 is sponsored by The Danish Industry Foundation as part of the project “Innovation on Wings”¹. The memo brings into focus successful uses of drones for inspection of infrastructure, but also aims to identify barriers to such missions in a Danish context. The memo is based on a qualitative study involving a range of core actors focusing on infrastructure development, inspection, and maintenance. A wide range of reports and articles serve as secondary data and shed light on the overall use and demand for drones for inspection of infrastructure.

It is not the ambition of this memo to offer estimations of market size for the different applications. Rather, the memo supplements existing reports by offering deeper insights into the opportunities and barriers for implementing drones for inspection of infrastructure.

¹ <https://www.uasdenmark.dk/testcenter/innovation-pa-vinger/om-projektet>

2 Why focus on drone applications?

The prospects for drones have been widely praised. Currently, the regulations for drone operations are limited to flying within visual line of sight (VLOS). To unleash the potential, beyond visual line of sight (BVLOS) operations must be legally permitted. It, however, requires a range of research objectives to be completed before drone air worthiness is established and safe flights are ensured.

The drone is characterized as a technology platform enabling a limited payload. Different types of drones are available on the market: Fixed-wing drones (similar to airplanes); drones with several horizontal propellers (multirotor drones similar to helicopters); and a hybrid, which is a fixed-wing drone that is capable of vertical take-off and landing. The payloads enabled include, e.g., thermal, electro-optical, infra-red, and multi/hyperspectral cameras; Radio/Light Detection and Ranging (RADAR/LiDAR); and particle/gas sensors, to name a few. Drones are controlled remotely by an operator or they are flying autonomously. From a Danish perspective, the latter requires substantial development related to failsafe software, communications and control equipment, and sense and avoid technology.



A multirotor drone. Photo: Jared Brashier on Unsplash

Drones are founded on a well-established and mature technology that has its origin within military applications, but more recently drones have enjoyed popular usage in the toy and leisure markets. There

is a growing trend towards adapting drones to applications related to civil and commercial use to fully realize their market value. When assessing potential missions, the drone application augments or replaces an existing solution that involves humans (e.g., helicopter inspection of power lines or rope-based inspection of wind turbines). The drone is anticipated to do jobs considered dirty, dull, or dangerous – at a lower cost and/or with less risk. Since drones are capable of quickly reaching remote areas, which may even be difficult to access, and then transmit, e.g. still photographs, thermal images, or video footage, they can provide the data for creating an overview of a given situation. Thus, drones serve as either an extension or a replacement of the operator for the effective accomplishment of varied missions. In this way, time, personnel, and money are saved.

Drones with mission specific cameras and payloads are already used for, e.g., inspecting wear and tear of wind turbines², searching for missing persons³, and getting an overview of a fire⁴. However, depending on the type of task, the drone is more than an “eye in the sky” or a “tattletale”. It is also an “errand boy” or an “enabler”, or even an “executer”, i.e., drones deliver goods, such as lab samples from medical clinics to hospitals⁵, or perform actual work, such as igniting an oil spill in the ocean⁶. Either way, each of these tasks require a specific combination of technologies and drone. This makes the full realization of the commercial market potential complex, as the many opportunities not only call for the development of the drone platform itself; there is also still a need for developing the payload, communication links, software programs, data analysis, training, and procedures to accomplish specific missions.

² <https://orsted.co.uk/en/Media/Newsroom/News/2018/07/The-future-is-here-automated-drone-robots-inspect-massive-80m-wind-turbine-blades>

³ <http://www.beredskabsstyrelsen.dk/viden/publikationer/Documents/trefoldet-drone-folder8.pdf> (in Danish)

⁴ <https://www.tvsyd.dk/artikel/brandvaesen-brugte-drone-faa-overblik-over-brand> (in Danish)

⁵ <https://www.theverge.com/2017/9/20/16325084/matternet-autonomous-drone-network-switzerland>

⁶ <https://blue-ocean-robotics.com/frontpage/bundles/offshore/oil-spill-handling/>

3 Using drones for inspection of infrastructure

Infrastructure covers a range of material and immaterial public facilities, which support the requirements of human life⁷. Infrastructure can be categorized according to the human needs that it supports, such as the need for water, light, heating, information, and mobility. In this memo, we have chosen to focus on the use of drones in relation to only some types of infrastructure, namely those meeting the needs for mobility, electricity, and heating. Thus, we have narrowed down the range of drone-enabled missions to inspection of roads and railroads, electricity supply, and heating supply.

There are several reasons why using drones to solve infrastructure-related tasks is beneficial⁸. These include, among others, reduction of both personnel, safety risks, environmental impact, facility downtime, and overall maintenance costs. First, costs can be reduced, especially as the inspections are today made by using more expensive helicopters. Second, safety can be improved by limiting the number of dangerous jobs (performed today by e.g. rope inspectors) and thereby protecting or even saving lives. And third, the environmental impact is reduced, since the use of drones means less CO₂ emission compared to the use of e.g. a helicopter. Nevertheless, the use of drones as a tool for inspecting infrastructure can also pose certain challenges. In this section, we present some examples and a few in-depth cases from a Danish context of both opportunities and barriers to the use of drones for such missions.

3.1 Inspection of road infrastructure

Drones equipped with sensors can be used to get an overview of road infrastructure, including detection of wear and tear, monitoring of the progress at a highway construction site, or analysis of traffic. For example, an Italian pilot project focuses on gathering traffic information to ensure more efficient and intelligent highways, which will be highly needed when self-driving cars enter the traffic system⁹.

Overall, it is beneficial to use drones for inspection of road infrastructure due to the volume (long stretch of roads) and thus the possibility to inspect longer distances at lower costs compared to e.g. helicopter missions. According to a case description in the Danish Drone Strategy from 2016¹⁰, The Danish Road Directorate finds that – compared to airplanes – drones are significantly cheaper to use for photographing smaller areas, whereas for mapping longer stretches of road, the expenses for airplanes and drones are approximately the same. But drones are regarded as being more flexible as they can quickly become airborne and as they are easier to maneuver. Moreover, they can fly underneath potential cloud ceilings and generate images and video footage, even when it is overcast.

⁷ Buhr, W. (2003). What is infrastructure? *Volkswirtschaftliche Diskussionsbeiträge*, No. 107-03: <http://hdl.handle.net/10419/83199>

⁸ European Drones Outlook Study. Unlocking the value for Europe, SESAR, November 2016

⁹ <https://www.architecturaldigest.com/story/how-drones-could-make-our-highways-more-efficient>; <https://www.carloratti.com/project/anas-smart-road/>

¹⁰ <https://ufm.dk/en/publications/2016/danish-drone-strategy>

The challenges to the use of drones are often related to the current legislation. In Denmark, it is forbidden to fly closer than 150 meters to bigger public roads and populated areas, unless a waiver is given by the Danish Transport, Construction, and Housing Authority. The Danish company, Dronops, has gained a dispensation from the Danish drone regulation for flying along and across a heavily trafficked freeway. The dispensation was issued by the Danish Transport, Construction and Housing Authority based on a risk assessment made by Dronops, which clarified that the drone would fly slowly and only be airborne on close to windless days. Moreover, the drone would fly high enough to go unnoticed and not distract the drivers on the freeway. Finally, in case the drone would crash, Dronops had rendered probable that it would land on safe territory. The mission went well.

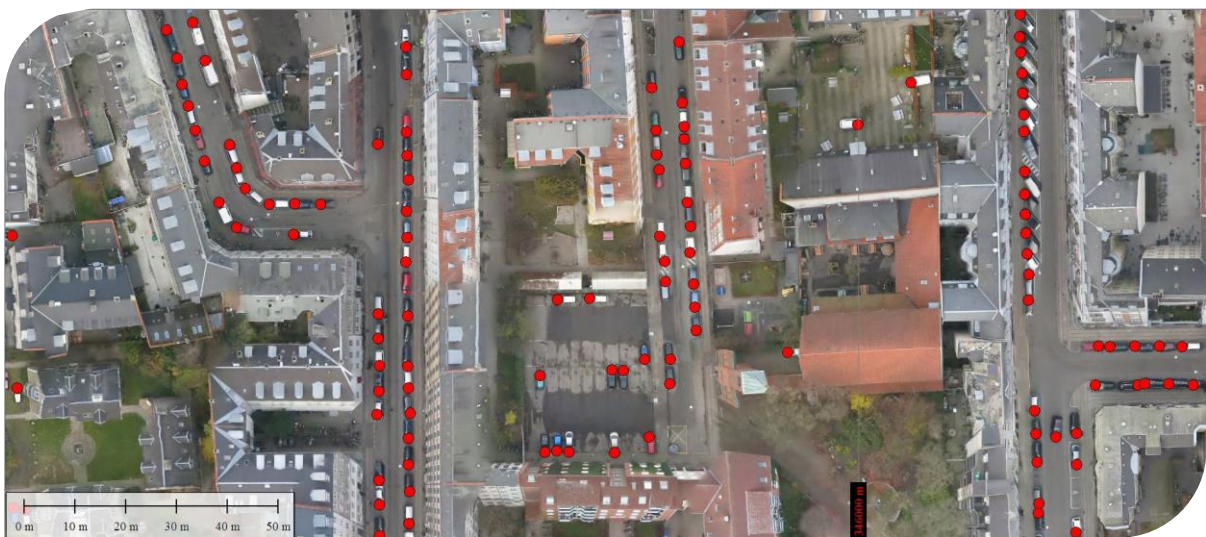
In collaboration with the company, Data From Sky, COWI has in recent years developed a software for monitoring traffic situations and aiding decisions on what precautionary measures to take. The solution includes an AI engine enabling an innovative new approach to the analysis. Data can be collected from various sensors, including a camera mounted on a drone. COWI uses a tethered drone, which is constantly powered through a cable from the ground and therefore enables up to a day of monitoring at e.g. 120 meters' altitude. After data collection, the moving objects in the video stream are vectorized. Based on factors such as the speed and density of cars, parked cars, the weather conditions etc., an analyst can then count objects, track speed and behavioral patterns over time, and analyze what happened, e.g. before an accident. The software solution is extensively used by a. o. the Danish Road Directorate, municipalities, and other organizations having a hot spot that needs to be analyzed¹¹. The method complements other data collection sources as it is very visual and self-explanatory. However, it only works under good climatic conditions (no flying when it rains, for example).



Traffic analysis in Copenhagen. Image: COWI and Data From Sky.

¹¹ <https://geoforum.dk/droner-monitorerer-trafikken/>

COWI has also developed a service using drones for traffic counting over a period of time. Another way of doing it would be having people write down number plates. However, this would be in violation with the EU General Data Protection Regulation (GDPR). Moreover, it is a very time-consuming task. Instead, COWI sends up small, fixed-wing drone that maps up to 0.5 km² in 30 minutes. This can be repeated every hour for a whole day or every day over a period of time. After processing ortho maps, it is then possible to count the number of cars and visually compare if a car has moved from one recording to another. This gives insights into long-term parking patterns and behaviors in city centers or parking lots. The method has been used by the City of Copenhagen to evaluate the effect of new paying zones in the inner city (before/after analysis), and the results has demonstrated a dramatic increase in parking capacity to the benefit of local residents¹². Moreover, the analysis showed a substantial potential in car sharing services, as up to 30% of all cars, in the areas, did not move over a working week.



Parked cars on a Friday at Vesterbro, a quarter of Copenhagen. Image: COWI.

In Denmark, many roads are owned by the municipalities, who are responsible for repair and maintenance and therefore constantly seek to obtain an overview of the state of the roads. As an example, the City of Odense wishes to generate a cross-section of its roads, including sidewalks, bikeways, curbs, lanes, road markings, etc. Traditionally, this has been done by a member of staff, who needs to block the road to ensure his safety while manually taking measurements of the cross-section. Generally, all roads need regular inspection to spot and repair any irregularities. This can be done by a few members of staff from a car or by walking the pavements. Once a year, the municipality orders air photos of the entire city. These photos are taken by means of a camera mounted underneath a small airplane. However, the resolution of the images is not high enough to enable detailed judgments about the state of the roads. The municipality would prefer having higher-resolution images to ensure a more efficient planning of repair and maintenance of the roads, e.g. by being able to measure the broadness of a specific stretch of road. The municipality has investigated whether drones can do the job, but found both technological and legislative barriers hindering the implementation hereof. Software must be developed and, importantly, the municipality will have to harmonize its digital systems to be able to import and operationalize the data gathered by the drones. And, as expressed by the municipality's Data Manager, Lars Fabritius de Tegnagel, *until the legislation will provide the opportunity to fly drones in*

¹² <https://www.berlingske.dk/samfund/se-forskellen-kabells-parkeringsplan-holder-pendlere-vaek-fra-koebenhavn>

urban areas – also in the daytime – drones are uninteresting. They entail too much administrative hassle, for which reason we are looking into a range of alternative technologies. He emphasizes that photos can be taken by means of a camera mounted on e.g. a stick or the municipality's garbage trucks. Thus, there are alternatives to existing means, but if drones could fly freely, whenever needed, they would be a good solution, he concludes.

3.2 Inspection of railroad infrastructure

Employing drones has great potential also in relation to railroad infrastructure, e.g. as it is seen in India, where drones are used for assessing the progress of railroad construction as well as the ground situation in the aftermaths of train accidents¹³.

In Denmark, the drone is one of more tools for generating data to monitor the existing situation. In pursuit of a digital transformation related to the Danish road and railroad infrastructure, Banedanmark (the Danish Railway) collaborates with the Danish Road Directorate on the use of BIM (Building Information Modelling), i.e. 3D digital models of the infrastructure¹⁴, which include the information for the whole lifecycle. To the end of ensuring a standardization of the foundation for project designs, there is a need for mapping e.g. terrain, among other things to be able to follow the progress of construction work. Traditionally, when mapping a stretch of railroad, land surveyors have carried out the measurements for every 20 meters or, more recently, helicopters or airplanes have been used for taking photos¹⁵. Drones can be used for generating so-called aerial photogrammetry of the terrain, which can generate three-dimensional information about the geometry and location of objects. Overall, this method is more accurate compared to taking photos from a helicopter or an airplane and can result in a more precise 3D model of the terrain. However, according to Gita Monshizadeh, Head of BIM/CAD Department at Banedanmark, photogrammetry cannot yet compete with laser scanning in generating precise 3D models of the terrain. In addition, a drone is not allowed to fly above or across a railroad unless this is out of operation and the drone pilot is within visual line of sight (VLOS) of the drone. In practice, this means that the pilot should at any time be at a maximum distance of one kilometer from the drone. These challenges have impacted the choice of tool and, according to Gita Monshizadeh, *the last time we used a drone to take measurements was prior to the renewal of Kystbanen (a stretch of railroad north of Copenhagen). This was around 2015, and we haven't tried it again.* Instead, Banedanmark receives data from an advanced laser scanner mounted underneath a small airplane. Gita Monshizadeh explains that the relevant scanner is too heavy to be mounted on a small drone, and the alternative of using a larger drone capable of carrying a larger payload entails higher costs. Thus, a drone solution is not yet competitive to existing alternatives. However, Gita Monshizadeh expects that a high-quality laser scanner small enough to mount underneath a drone will soon be available. Such progress could make Banedanmark consider using drones again.

¹³ <https://indianexpress.com/article/india/india-news-india/indian-railways-drones-to-inspect-progress-of-mega-rail-projects-irctc/>

¹⁴ <http://biminfra.dk/>

¹⁵ <https://ufm.dk/publikationer/2016/danmarks-dronestrategi>

3.3 Inspection of electricity infrastructure

Drones can be used for missions to e.g. support operations at power plants. Duke Energy, a US utility company, is using drones and considers making them part of the company's operations¹⁶. According to the company, drones improve safety as well as operational and performance costs in connection with e.g. inspection of large hard-to-reach boilers at power plants, inspection of solar farms to assess panels that are not operating correctly, and for getting an overview of the work needed after major storms.

Drones can with advantage also be used for inspection of electricity networks due to the long stretch of power lines (within EU alone, there is around 200,000 kilometers of power lines) and thus the need for extensive inspection over long distances. The US-based company, Airbus Aerial, partnered with a bigger utility company, Southern Company, to demonstrate the usability of aerial technologies to inspect power lines¹⁷. The demonstration used a mix of Airbus satellite systems and a drone. This combined drone and satellite operation was the first in that area where the drone flew beyond the operator's visual line of sight while performing the mission.

3.3.1 In-depth case no. 1: Drones for inspection of many kilometers of power lines

Energinet, the owner of the Danish electricity transmission network, has identified several advantages of using drones for inspecting its high voltage power lines and towers. Equipped with a high-resolution camera, drones will be able to fly along the approximately 7,000 km of power lines to register corrosion and other issues that eventually lead to critical malfunctions. Subsequent analysis of the pictorial material can ensure timely detection of wear and tear to prevent expensive and unnecessary downtime of energy supply. Thus, the use of drones in this area shows promise.

Today, Energinet orders visual inspections of its power lines and towers once a year. The job is normally carried out by an inspector aboard a helicopter, who takes pictures of potentially critical areas that he may observe on the power line. This is a both expensive, risky, and somewhat imprecise way of collecting data. Mobilizing a helicopter, the pilot, and an inspector is costly and takes time. Moreover, the helicopter must be kept at a safe distance (25+ meters) from the power lines, which makes it difficult to ensure high-quality images.



A damaged strand on a power line, captured by means of a drone. Image: Scopito.

¹⁶ <https://illumination.duke-energy.com/articles/drones-go-where-man-has-gone-before/>

¹⁷ <https://airbusaerial.com/airbus-aerial-southern-company-team-first-kind-inspection-power-lines-georgia/>

If the inspector suspects corrosion or damages, a drone pilot from the company Geopartner Inspections is hired to do a more thorough registration of specific sections of the infrastructure. The high-resolution pictures taken by the camera on the drone is uploaded to the cloud-based software of Scopito, and Energinet can then investigate the images to decide what repair and maintenance is needed immediately and what may be postponed until later. Overall, this means that the downtime of the electricity transmission network can be reduced to a minimum.

Compared to a helicopter, a drone is easy to mobilize, can be controlled at a distance or in the future even fly autonomously, and then get very close to the power lines and the towers. The result is pictures of a higher resolution at a lower price. According to Lars Rasmussen, Group Leader of Maintenance at Energinet, *“the drone inspection meant that we all of a sudden could identify some other errors, because we got these very, very detailed images”*. Until now, the helicopter remains part of the inspection solution – at least until a few barriers to the full implementation of drones are eliminated.

Legislative barriers. Together with Geopartner Inspections, Energinet started testing the drones for inspection of power lines as early as 2014. This did not go unnoticed. The focus on and positive expectations for drones were highlighted in Denmark’s drone strategy in 2016¹⁸, and in January 2017 it was announced both nationally¹⁹ and internationally that Energinet and Geopartner Inspections would very soon get a waiver – i.e. an exemption from the Danish legislation – that would enable drones flying fully autonomously, beyond visual line of sight (BVLOS), along the power lines. However, today – two years later – it is still not allowed to fly BVLOS. Thus, a drone pilot still needs to be present and able to see the drone as it flies along the power lines. Lars Bach Poulsen, Land Surveyor and Day to Day Manager at Geopartner Inspections, explains that getting the permission *“turned out to be a bigger task than we had predicted. And then some new regulations came from JARUS²⁰, and we had to redo the applications according to the SORA”*. Thus, a main reason for the delay is that the upcoming European drone legislation contains the JARUS (Joint Authorities for Rulemaking on Unmanned Systems) guidelines on Specific Operations Risk Assessment (SORA), which Geopartner Inspections must already now seek to comply with. Basically, the company must render probable that the drone can fly safely and ensure that it will (most likely) neither fall to the ground and hurt someone nor make a so-called fly away and collide with an airplane. Ensuring the necessary documentation is time-consuming. However, according to Lars Bach Poulsen it is *positive that one has to have everything under control – and not just fly a drone completely uninhibited*. This prevents drone inspection companies to cut corners. The final SORA document was approved on March 4th, 2019. The approval implies that there will soon be a standardized process for operating drone companies to comply with, which puts demands on training, safety, and having operational programs in place with relevant contingency and emergency procedures established and practiced. SDU UAS Center has conducted test BVLOS flights around HCA Airport with Geopartner Inspections in late 2016 and more flights are expected. SDU UAS Center has, as the first in Denmark, been granted authorization to conduct autonomous BVLOS flights under the coming European regulations and has since September 2018 demonstrated successful flights²¹.

¹⁸ <https://ufm.dk/publikationer/2016/danmarks-dronestrategi>

¹⁹ https://www.energy-supply.dk/article/view/309822/danske_firmaer_far_gront_lys_til_selvstyrende_drone

²⁰ The JARUS guidelines on Specific Operations Risk Assessment (SORA): http://jarus-rpas.org/sites/jarus-rpas.org/files/jar_doc_06_jarus_sora_v1.0.pdf. A recommended risk assessment methodology to establish a sufficient level of confidence that a specific drone operation can be conducted safely.

²¹ https://www.sdu.dk/en/om_sdu/institutter_centre/sduuascenter/significant+achievements/bvlos+flight

However, it is possible that BVLOS operations in general across Denmark will not take place until a more organized airspace management system (U-Space and UTM) as well as the technical platform and communications standards are fully developed. Moreover, SORA is replete with requirements for “third party verification”, which place demands on each nation to have a set-up for handling verifications. The non-profit organization, UVS International, has organized an industry stakeholder group to help implement the regulations and address the associated challenges. The goal is *to make it possible for the drone community to actively contribute to and speed up the harmonization of the national approaches in the European Union relative to the implementation of the upcoming European drone regulation*²².

Technical barriers. A main barrier to overcome to support BVLOS flights is the development of the infrastructure in the form of an unmanned traffic management (UTM) system. This is currently the focus of U-Space in Europe. Companies such as Unify, Eurocontrol, Airbus, Integra, Navair, and others are involved in developing the airspace communications, control, and deconfliction. Another technical barrier is battery life. The battery life of the DJI Matrice 600 standard drone that Geopartner Inspections uses at the moment is around 40 minutes. If BVLOS flights are allowed, Geopartner Inspections could also use a fixed-wing drone that can fly considerably longer before recharging is needed. Thus, the company will be better able to take advantage of a BVLOS permission for power line inspection by changing to a different drone. This is a trouble-free maneuver. However, BVLOS flights generate large amounts of images and, hence, data that must be stored and analyzed. Energinet already uses Scopito’s cloud-based inspection software, which can store and handle millions of images and ensure a quick analysis by applying a combination of machine learning and human intelligence. Therefore, as explained by Ken Falk, CEO of Scopito, *“When using Scopito’s analysis, Energinet can concentrate on let’s say 70 relevant images (of e.g. specific insulators) instead of having to look at thousands.”*

The future use of drones. Lars Rasmussen from Energinet envisions letting drones perform instant inspections whenever Energinet receives a notification of a possible fault on the electricity transmission network. At a distance, Energinet can typically locate the error within three to four towers and can then order a drone inspection accordingly. Another future use of drones for inspection of power lines is currently being developed as part of the research project, Drones4Energy, led by University of Southern Denmark²³. The idea is to develop a swarm of four autonomous drones that will be wirelessly connected. From each their angle and within a distance of a few meters to the power lines, they will collaborate to detect any errors. Interestingly, the drones will be able to recharge their batteries by hooking on to the power lines. The project therefore also focuses on developing a light-weight “energy harvester” that can be carried by the drones. Moreover, it is the ambition to enable the drones, by means of onboard processing of the data, to send only relevant information to the operator about the power lines being inspected. Thus, Energinet would only have to analyze and store relevant data. Overall, the project is expected to cut up to 95% of Energinet’s costs for inspection of the power lines, which is currently based on a combination of helicopter and manual drone inspection.

²² https://rpas-regulations.com/wp-content/uploads/2019/04/190426_Drone-REGIM-Update_TR.pdf

²³ <https://ing.dk/artikel/selvflyvende-droner-skal-finde-fejl-paa-hoejspaendingsnettet-221930>



A drone in the sky inspecting power lines.
Photo: Geopartner Inspections.

Energinet is an independent public company under the Danish Ministry of Energy, Utilities and Climate. The company owns the Danish electricity and gas transmission networks and focuses on implementing more renewable energy and maintaining energy security. www.energinet.dk

Geopartner Inspections offers precise surveying, mapping and inspection of buildings, technical facilities and infrastructure by means of drones, GPS, laser scanners, etc. The nature and extent of a task define the choice of technology. Geopartner Inspections is part of Geopartner Landinspektører Holding. www.geopartner-inspections.com

Scopito offers to simplify complex (drone) inspections by means of its cloud-based software that helps clients store, analyze and share large amounts of image-based inspection data. www.scopito.com

3.4 Inspection of heating infrastructure

Drones are used for detecting leaks in district heating pipeline systems; an area which is currently under fast expansion. Locating leaks and defects in the insulation of heating pipes below ground level is possible by using a thermal camera, since any leak of hot water also causes heating of the ground around it²⁴.

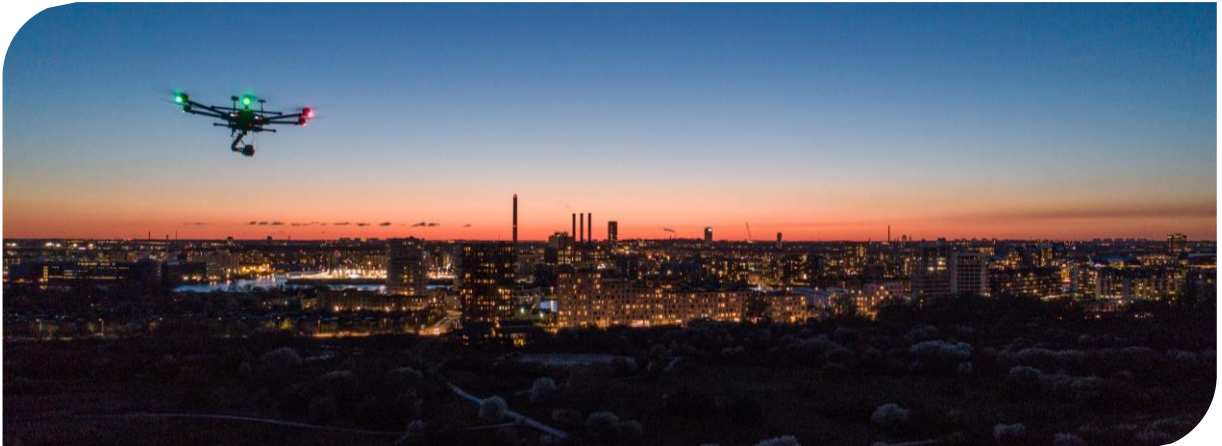
More and more Danish district heating plants are employing drones to take thermographic images of their pipeline network with the aim to map the network and discover possible leaks. One of many district plants that employ drones to find leaks in the heating pipelines is Aalborg Varme, assisted by the drone operating company Drone Systems²⁵. The aim of this initiative is to track leaks that need to be fixed to improve the effectivity of the heating supply. The accuracy of the images can help narrow down the possible areas of a leak and thereby to avoid having to open many meters of pipelines to detect a leak. The payload on the drone can read temperature differences on the ground from 100 meters height, and the focus is on pipelines running towards and close to customers' homes. Usually, inspections would be made by driving a car with a thermographic camera mounted on the roof along the 1,700 km long pipeline network, but e.g. in areas with no or limited access for cars, drones come in handy.

²⁴ <https://www.workswell-thermal-camera.com/inspection-hot-water-warm-water-pipes/>

²⁵ <https://nordjyske.dk/nyheder/droner-finder-utaetheder-i-fiernvarme-roer/90764baf-c0e6-45fc-9cac-a682c8e3976e>

3.4.1 In-depth case no. 2: Mapping of Copenhagen's heating pipeline network

The utility company, HOFOR, also uses thermal images taken by means of drones to detect leaks in the heating pipeline network of Copenhagen²⁶. According to HOFOR, the use of drones has enabled a more exact overview of the state of the pipelines and thereby a more efficient planning and repair of damages. This is a rare case of drones being authorized to fly in a densely populated area in Denmark – with great success.

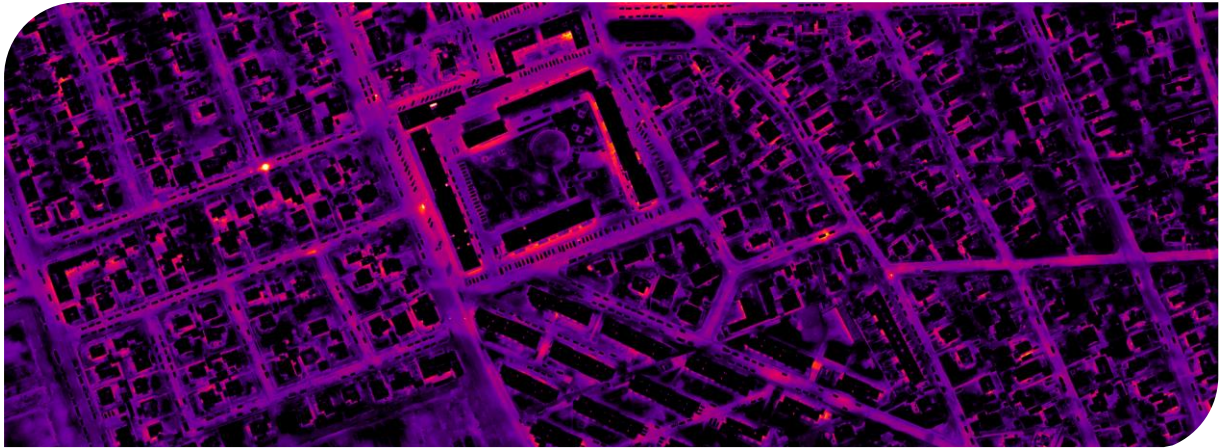


Drone flying above Copenhagen at night. Photo: HOFOR

At the end of 2016, HOFOR started collaborating with the company, Drone Systems, on a drone-based solution for gaining a better overview of the state of Copenhagen's heating pipeline network and thereby optimizing its repair and maintenance. In Copenhagen, it is impossible to take high-quality thermographic pictures by means of airplanes, as there is too much thermal pollution, but also due to the large amount of high buildings and the location of the heating pipes in inaccessible places such as backyards. Before implementing drones, HOFOR's employees drove the streets of Copenhagen and used a hand-held thermal camera. This solution only enabled inspection of the main roads, whereas drones equipped with a thermal camera can also inspect the many meters of pipeline from the main roads to people's private property, backyards, and gardens. Moreover, leakages are localized with a precision of less than one meter, which saves both time and money in connection with repair work. According to Bo Jensen Møller, Head of Operations Management at HOFOR, the use of drone *has significantly increased accuracy. And the consequential damages are now less, because we can detect them earlier.*

When HOFOR's employees discover a leakage in a private property's roof, facade, or internal heating pipelines they can warn the property owner. According to Nina Maria Klok, Communication Advisor at HOFOR, *it is in tune with our mission that we, as a result of spotting leakages faster and more precisely, can improve the district heating network and sometimes even help a property owner save energy.*

²⁶ <http://www.danskfjernvarme.dk/magasinet/nyheder/170201-nyt-fjernvarmen-er-p%C3%A5-gaden>; <https://ing.dk/artikel/droner-soeger-efter-laekager-koebenhavnske-fjernvarme-192924>; <http://www.hofor.dk/nyhed/droner-finder-laekager-i-hovedstadens-fjernvarmenet/>



Thermographic overview of the state of Copenhagen's heating pipelines. Image: Drone Systems for HOFOR.

Overall, the implementation of drones for inspection of Copenhagen's heating pipeline network is a success. However, there are certain barriers to consider before a fully efficient use of drones is a reality.

Legislative barriers. According to the current Danish drone legislation, flying within urban areas should only be done with a professional purpose, and it is necessary to obtain special permissions from the Transport, Construction and Housing Authority. Drone Systems is licensed to fly within urban areas at night using all types of drones under 25 kg. Technically, it is required that it must be both dark and cold outside when performing the thermal mapping of the heating pipeline network. Therefore, the flights take place at night from November to April. Before flying a route, permissions from authorities, such as the police, and directly affected citizens must be obtained. This is burdensome for the company, but Drone Systems has been able to get all the permissions needed to perform the missions for HOFOR. However, BVLOS flights are still not allowed. In practice, this means that Drone Systems can preprogram the air route of the drone, but the pilot must be able to see the drone anytime and take control of the drone, if necessary. In practice, the drone flies at 80-120 meters altitude with the pilot centrally positioned at intersections, squares, or even at private roof terraces (by prior agreement, of course), so that he can see the drone all the time.

Mapping the state of Copenhagen's heating pipeline network includes having to fly around restricted areas of Copenhagen Airport. Drone Systems has established a good collaboration with Naviair, the navigation service and traffic control of the Danish airspace. Michael Noer-Hvarre from Drone Systems explains that *we have a direct line to the control tower, so that we are informed when an airplane is approaching the airport. We then must land the drone and wait a bit.* In practice, since Drone Systems only flies between 11 pm and 6 am, air traffic is not particularly dense. Another restricted area that Drone Systems has obtained permission to fly in, is the area of the national hospital, where drones must give way to helicopters that take-off and land. Drone Systems must also ask the embassies for permission to fly around their properties. This is usually not a problem; although, the US embassy never allows drones in its safety zone.

Drone Systems welcomes the upcoming EU drone legislation, as it will enable the company to more easily offer its services in other countries. However, a downside is that member states can still, to some extent, define their own rules, which can result in different drone regulations across Europe. This can become a barrier to companies aiming at establishing their businesses abroad.

Technical barriers. Drone Systems uses a DJI S1000 drone with eight propellers, double steering system, and double battery package to ensure redundancy. The platform is continuously under development, as there is not a standard product on the market that is suited for these particular missions. Moreover, Drone Systems has had to 3D-print a “house” to protect the sensor payload, which must be kept constantly at the same temperature and is easily affected by the weather conditions during flights.

Public reactions. Research shows that privacy and safety concerns can be problematic aspects related to the use of drones²⁷. First, people are afraid that drones may capture inappropriate information and intrude their private sphere. Lack of information about drones and the missions they are performing can cause anxiety and insecurity, as people are unable to assess if their privacy is being violated or not. People’s response and tolerance towards drones are higher if they know more about the drone, who is responsible for it, and what the intention behind flying it is. Second, people are more tolerant towards drones used by public authorities or performing public service tasks, as such missions are regarded valuable. And third, people generally trust professional pilots more²⁸.

HOFOR makes an active effort to inform the citizens of Copenhagen, who will be overflown by drones. The strategy is to communicate through different channels and provide as much information as possible about what the drone is doing, why it is there, and why it is a good idea, i.e. that the drone helps ensure that the heating pipeline network works properly. Moreover, HOFOR emphasizes that no citizens will be filmed, since the drone is only carrying a thermographic camera. A challenge in relation to informing the citizens is that the drone operations depend on the weather conditions and therefore cannot always be carried out as planned. HOFOR accordingly indicates a time span and uses mainly its own website and social media, as information flows quickly to the public. Nevertheless, the public in the affected areas is also informed through local newspapers and TV channels as a means of reaching especially senior citizens. Fortunately, the public reactions to the use of drones for mapping the heating pipeline network have thus far been positive.

Finding the leakages has been a challenge for HOFOR for many years. Therefore, the thermographic pictures taken by the drone, the way the data is presented, and the possibilities and flexibility for handling the data are of value to HOFOR. Even though customers cannot feel the difference in their heating supply, if there are leakages on the pipeline network, finding these leakages is necessary to improve energy efficiency and to advise the public on how to save energy. Bo Jensen Møller explains how HOFOR made a comprehensive cost-benefit analysis of the pilot project, which showed a return on investment within 3.5 – 4 years. This is satisfactory, but the most important benefits of using the drones are better detection and ensuring more efficient leakage repair.

Through 2,888 kilometers of pipelines, **HOFOR** supplies 600,000 people in the Copenhagen metropolitan area with district heating. HOFOR also supplies Greater Copenhagen with drinking water, district cooling, town gas, and disposal of wastewater. HOFOR’s vision is to create sustainable towns and cities based on climate-friendly and environmentally safe supply solutions. www.hofor.dk

Drone Systems is specialized in conducting thermographic inspections by means of drones with the purpose of analyzing and streamlining energy solutions. The company flies drones and develops the software platform, TeraPlan, to manage the data. www.dronesystems.dk

²⁷ <https://www.sdu.dk/en/dronepublic>

²⁸ General public’s privacy concerns + Public reactions to drone use in residential and public areas: https://www.sdu.dk/en/om_sdu/institutter_centre/i_marketing/forskning/forskningsprojekter/drone_public

4 Barriers and opportunities

The public in Denmark has in general few concerns regarding the implementation and use of drones in society²⁹, and many owners of infrastructure have identified relevant benefits of using drones for inspection of their facilities. Thus, based on expectations for reduced inspection costs and/or high-quality images, there is a considerable market for drones for such missions. However, the drone service providers face certain barriers to carrying out the jobs.

- Generally, drone service providers must be able to offer a solution to the analysis of the data, e.g. the images, that are captured by means of drones. The owners of infrastructure may not be ready to implement the type of data that the drone collects and may not be prepared to analyze the image materials. Thus, a digitization effort in the company may be necessary to take full advantage of the drone-based solutions.
- For safety reasons, the Danish drone legislation generally prohibits flights beyond visual line of sight (BVLOS). Although it is time-consuming, it is possible to obtain permission for flying a drone within extended visual line of sight (EVLOS), which enables the mapping of longer stretches of roads, power lines, etc. without having to land and go to the drone for every kilometer or so. To take full advantage of the drone, it is required that BVLOS missions are allowed, which requires a change of the current legislation.
- According to Christian Clemmensen, Dronops, who has a background from the highly regulated military aviation in the Danish Defence, many drone service providers do not know how or do not have the resources or motivation to make the necessary mission applications. Spending time on identifying the possibilities within the legislation, formulating missions, identifying associated risk mitigations, and having a constructive dialogue with the Danish Transport, Construction and Housing Authority can pay off. Moreover, the commencement of the European drone legislation³⁰ in June 2019 is expected to simplify things, as it will contain pre-defined mission scenarios that a drone service provider can refer to, when applying for a dispensation. Already today, the Danish Transport, Construction and Housing Authority has published standard scenarios for limited BVLOS flight with drones for rescue missions³¹, where an increased risk is accepted and certain mitigating procedures according to the Specific Operations Risk Assessment (SORA) are not required. In general, such standard scenarios will expectedly enable drone service providers to more easily apply for dispensations.
- If the upcoming EU legislation leads to harmonized rules, it will make it easier for providers to start offering drone services across national borders. However, each EU nation will be allowed to establish its own geographical zones for drone flights³² and e.g. declare a city a no drone area.
- Freeing the drones by allowing BVLOS flights more generally will not be a reality until a traffic management system for unmanned aerial vehicles such as drones is implemented.

²⁹ <https://www.sdu.dk/en/dronepublic>

³⁰ http://ec.europa.eu/transparency/regcomitology/index.cfm?do=search.documentdetail&Dos_ID=17242&DS_ID=58829&Version=4

³¹ <https://www.trafikstyrelsen.dk/DA/Luftfart/Flyveoperationer/Luftfartserhverv/Droner-i-redningsberedskabet.aspx>

³² <https://www.trafikstyrelsen.dk/DA/Luftfart/Forum/Droneforum.aspx>

- Although the majority of the technology needed is already developed, flying BVLOS without asking for permission will by and large not be possible until it has been demonstrated, by means of sufficient flight hours, that drones are safe. In that connection, Christian Clemmensen from Dronops brings into focus the need for drone maintenance procedures. There are no such requirements today. However, the upcoming EU legislation puts demand on the pilot to ensure that the drone is “in order” for the intended mission.

Despite these challenges, the fields of application for drones in infrastructure contexts are numerous. And the implementation of drone technology will continue. However, for drone service providers to succeed in the marketplace, it requires a focused and continued effort, especially to ensure that:

1. The risks and mitigating procedures associated with drone missions are described in accordance with the SORA (Specific Operations Risk Assessment) guidelines.
2. The necessary permissions for conducting drone mission are in place, which typically involves a dialogue with the Danish Transport, Construction and Housing Authority – or the traffic authorities of other countries that may be the target of the drone service provider.
3. The citizens affected by drone missions are adequately informed to avoid negative reactions.
4. The data captured by means of drones are accessible and useful to customers, even though they may not have compatible systems.

5 Methods

This memo draws on a combination of desk research and primary data. Semi-structured interviews (Table 1) were conducted with a range of stakeholders in Denmark between April and September 2018 by researchers from the University of Southern Denmark (SDU). The interview data was transcribed and coded to enable categorization and analysis of the most important aspects in relation to the use of drones in infrastructure contexts.

Role	Organization	Interviewee	Position in the organization
Drone technology and/or service provider	COWI	Stephan Mølviq	Specialist, Geoservices
		Annika Vestergaard	Trainee
	Drone Systems	Michael Noer-Hvarre	Chief Marketing Officer
	Geopartner Inspections	Lars Bach Poulsen	Land Surveyor and Day to Day Manager
	Scopito	Ken Falk	Founder and Chief Executive Officer
Experts on drone regulations	Dronops	Christian Clemmensen	Founder and Drone Specialist
	SDU UAS Center	Brad Beach	Center Leader
(Potential) customer	Banedanmark	Gita Monshizadeh	Head of BIM/CAD Department
	City of Odense	Lars Fabritius de Tengnagel	Data Manager
	Energinet	Lars Rasmussen	Group Leader, Maintenance
	HOFOR	Bo Jensen Møller	Head of Section, Operations Management
		Nina Maria Klok	Communication Advisor

Table 1: Overview of the interviewees who kindly contributed to this memo.

www.uasdenmark/innovation-paa-vinger.dk/