Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 72 (2023) 1747–1754

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Is Urban Air Mobility Environmentally Feasible? Defining the Guidelines for a Sustainable Implementation of its Ecosystem

Marta Tojal[a1], Ligeia Paletti[a]

[a]*Royal Netherlands Aerospace Centre, Amsterdam, the Netherlands*

Abstract

Urban Air Mobility (UAM) is commonly branded as the upcoming sustainable form of air mobility. Within the aviation sector, the adjective "sustainable" is almost exclusively used in relation with new forms of propulsion, particularly to electric and/or hydrogen energy sources, and in relation to noise levels caused by aviation activities. The same seems to apply for UAM. Limiting a sustainability assessment to the level of emissions (of all types) or of noise is not enough to generate a sustainable mobility system. This paper reviews the state of the art in the field of UAM and wants to assess how much the full meaning of "sustainability" is used in relation to UAM. Moreover, the paper reviews and defines a set of indicators to measure the sustainability of UAM.

Keywords: sustainable mobility; decarbonisation; circular economy; drones; smart cities; urban mobility.

1. Introduction

Urban Air Mobility (UAM) has gained popularity in the past decade as the next revolution for mobility. It promises to be a more efficient and sustainable form of transport, using the unutilized airspace in urban environments to improve services and mobility. In this context, the term "sustainable" is often misused, referring only to emissions produced during operations or to the propulsion technology. This misunderstanding is applicable not only to UAM, but to the whole (air) transport sector in general.

In 1987, the United Nations (UN) defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development's , 1987) This encompasses not only environmental sustainability, but also social and economic sustainability (McGill

[1]* Corresponding author. Tel.: +31 88 511 36 84.
E-mail address: marta.tojal.castro@nlr.nl

2352-1465
10.1016/j.trpro.2023.11.649

University , n.d.). Taking this definition as a basis, the authors aim to provide clarity on what should be the real meaning of sustainability in reference to UAM.

The following methodology was used to carry out this study: firstly, a literature review was performed, looking at the current sustainability status of UAM, in terms of the vehicle, infrastructure, and operations. Secondly, the authors reviewed different sustainable indicators and their applicability to UAM. Simultaneously, interviews to experts were carried out, to understand the views on the topic from different UAM stakeholders (academia, research, and authorities). Finally, the authors analysed the gathered information, giving an overview of what it should be understood as sustainability in UAM and the way forward to make it a reality.

2. Literature review

This section provides an overview of the current status of sustainability in the following aspects of the UAM ecosystem: vehicle, vertiports and operations.

2.1. Vehicle

Based on the information publicly available regarding the vehicles' developments, a variety of designs for the Unmanned Aircraft Systems (UAS) are considered, though electric Vertical Take-off and Landing (eVTOL) has been identified as the preferred type of design for UAM vehicles, with 600 eVTOL concepts have been identified since 2016 (The Vertical Flight Society , 2022). Through the overview of the industry performed, it appears that limited or no attention is given to the environmental impact of manufacturing the UAM vehicles and their propulsion systems, or to include end of life considerations.

Publicly disclosed information on the materials considered for the vehicles are limited to the choice of materials and are consistent with the trends and developments in the traditional aviation industry. No environmental or sustainability consideration in terms of design approaches or material selection is provided; only in one case, the circular economy approach of design for modularity is mentioned.

Following the conventional aviation trend regarding electrification, the design of the batteries for UAVs focuses on efficiency and duration, while minimizing structural weight, with no consideration of the sourcing or availability of the needed materials. This means in several cases the focus is on structural batteries or other concepts for which repairability or reusability is not possible (yet).

It may seem premature to discuss aspects related to end of life of UAVs, given the status of the industry. Nonetheless, the number of vehicles entering the market is forecasted at 430000 units by 2040. Combined with the trends in the mobility sector and the push of some governments to have self-sufficient supply chains, this suggests that end-of-life aspects should already be considered. For example, in the automotive sector, the European Union end-of-life directive has stimulated Original Equipment Manufacturers (OEMs) of electric vehicles to seek partnerships with different sectors (e.g. smart energy), to repurpose automotive batteries and to investigate circular design approaches (Renault Group, 2017) (BMW, n.d.).

2.2. Vertiports

Vertiports are one of the main enablers for UAM. This infrastructure will provide a city hub where vehicles can take-off, land, recharge, and pick-up or leave cargo and passengers. The literature about vertiports (Karolin Schweiger, 2021) (Skyports, Wisk, 2022) focuses on the technical and operational challenges: the final approach and take-off area, taxi ways, charging infrastructure, safety aspects, etc, ; failing to address a critical aspect for the design of a vertiport: its sustainability.

Initial research is being done for the design of sustainable vertiports. In most cases, sustainability is mentioned as a requirement for the successful implementation of vertiports, especially highlighting the challenge of noise nuisance, yet without explanation of how this sustainability may be reached. Only one report addresses the topic in depth, the Venice Biennale (2016), for the design of socially impactful and sustainable vertiports. The report provides insights into Norman Foster's views; a vertiport should be in line with the architecture of the city, using local natural materials, looking into the full life cycle of the infrastructure, and the integration of the building in the city. Even though vertiports will be used mainly by drones, they should have a multimodal and multifunctional characteristic, serving as a hub for other business related to the UAS. Overall, the report makes an emphasis on the importance of vertiports being socially sustainable buildings.

The Design for Adaptation (DFAD) concept is mentioned in architectural design literature to achieve sustainable and socially impactful products (Kasardaa, et al., 2007), (Blevis, et al., 2017). This concept promotes the design of modular and dynamic systems that are capable of adapting and evolving for an extended lifetime and impact on sustainability goals. The DFAD concept provides guidance for the development of vertiports in cities: the design should be dynamic, and include an examination of biological, cultural and technical systems to identify the characteristics allowing a successful adaptation for longevity.

When looking at vertiport concepts published by the industry, sustainability is mentioned to a certain extent. Concepts like the ones published by Lilium (2020) or eHang (2021) mention modularity or sustainable materials, respectively. Bayards (n.d.) proposes aluminium as the main material for vertiports to achieve weigh reduction, corrosion resistance and durability. Despite these examples, there is not enough evidence of environmental and social sustainability being taken as a critical aspect for the development of vertiports. Given the early stage of this industry, it is still possible to define sustainability as a requirement for the development of vertiports. Regulation, standards and industry should address this aspect in future publications, ensuring that vertiports are designed in a durable and socially impactful manner.

2.3. Operations

Due to the trend of developing electric powered UAS, the discussion on the sustainability of operations and routes is usually disregarded. When it comes to the link between operations and sustainability, the literature focuses mostly on noise and visual pollution, not really touching upon how routes should be designed to optimize energy use.

The project CORUS-XUAM (Çetin, et al., 2022) investigated possible measures to improve public acceptance of drone operations. In that research, measures to mitigate sustainability concerns were proposed, such as:

- Use of renewable energy sources to recharge batteries and use of sustainable aviation fuel for hybrid drones.
- Identify strategic locations for vertiports to optimise routes.
- Design optimized arrival and departure operations.
- Ensure proper maintenance processes and controls for batteries to extend their lifecycle.
- Work with eco-friendly drones (recycled parts).

The design of the vehicle may have an impact on the environmental impact of operations. According to Kasliwal, et al., (2019), distributed-propulsion VTOLS are the preferred design in terms of sustainability, as it yields the most energy efficiency while also achieving significant noise reduction.

Moreover, trip distance should be taken into account when analysing the environmental impact of operations (Kasliwal, et al., 2019). UAM vehicles, and especially VTOL aircraft, are not energetically efficient in short distances due to the hovering phases of the flight. In fact, when compared to internal combustion engine vehicles and battery electric vehicles, VTOL aircraft start to be more efficient than internal combustion engine vehicles only from 35km onwards, while battery electric vehicles are always more efficient than VTOLs. This highlights the need for UAM to be complimentary to other transport modes, only making use of it when it makes sense operationally and economically.

3. Sustainable indicators for UAM

To implement a sustainable system, indicators are needed to measure aspects of UAM against an environmental benchmark. The following section provides an overview of existing sustainable and circular economy indicators, as well as sustainable mobility indicators, analysing the applicability of the latter to UAM.

3.1. Sustainable and circular economy indicators

Sustainability is a complex concept, which cannot be solely translated into a quantitative indicator. This complexity is visible in the current status of sustainability metrics and indicators, their variety, and lack of standardisation. The most widespread sustainability certifications are those developed by Science Based Targets and by B Corp Movement. Those certifications embrace a broad meaning of sustainability, represented by the UN Sustainable Development Goals (SDGs). Another indicator for environmental, societal and governance (ESG) targets is represented by the ESG criteria, seen as increasingly important to investors. Another indicator, based on life cycle assessment (LCA), is the environmental product declarations (EPD). Regarding circular economy, or circularity, the main source of metrics and tools is the Ellen McArthur Foundation and the Material Circularity Indicator (MCI). A similar metric is used to calculate the Circularity Gap Report, released by Circle Economy, but several other indicators are also in use to assess circularity (Moraga, et al., 2019).

The evaluation of the environmental impact, footprint, and circularity in the aviation industry is still topic of research. Currently, given the narrow meaning of sustainability in the aviation sector, environmental targets and goals are expressed mainly in terms of carbon emissions, sometimes in more general terms as Greenhouse Gas (GHG) emissions (Cox emissions, NOx emissions, etc.), and of noise levels or various pollutants. Other forms of nuisance, which relate to "Quality of Life", refer to indicators which are of subjective or of qualitative type (for example, ranges of favourable-not favourable), as in the EASA study on public acceptance of UAM (2021). The most common indicator for environmental impact is LCA, but the obtained results are highly variable, mainly following the scarcity of data or the boundaries used in the LCA assessment.

To the authors' knowledge, none of the existing metrics for sustainability or circularity has ever been applied specifically to the UAM industry. Various players in the industry present figures in terms of GHG or noise reduction, but the methods or data used to determine the presented figures are never substantiated. Similarly, LCAs of UAM, UAS or related infrastructures are unavailable to the public. This means that all provided reduction in GHG emissions cannot be verified independently, also given that the majority of the estimates are based on concept vehicles.

Stepping away from specific environmental assessments, companies in the traditional aviation sector are more and more committing to meet SDGs or other sustainability targets at corporate level. OEMs and airlines in the traditional aviation sector are already setting ESG or EPD targets and seeking B Corp certification. For example, regarding ESG (S&P Global , 2019), the overall transport system ESG risk score of 7, while the Aerospace and Defence sector of 6, in a scale of 1-12, with each component (Environmental and societal) evaluated individually in a scale 1-6. The classification of UAM to one of the two sectors is not yet defined; nonetheless it is noticeable that the risks are equally distributed between the environmental and the societal contributions. This should warn companies in the UAM market (as it does with traditional aviation players) that focusing only on environmental aspects (such as the focus on electrification and emission-free vehicles) is not sufficient.

Given the peculiar nature of UAM vehicles, a possible framework to consider is towards an ecolabelling system aligned with the current EU directive on car labelling, which requires EU countries to provide relevant information to consumers, including a label showing a car's fuel efficiency and its CO_2 emissions.

3.2. European sustainable urban mobility indicators

The Sustainable Urban Mobility Indicators (SUMI) are a set of metrics defined by the European Commission to help cities measure the quality of their mobility system in terms of environmental and social sustainability (European Commission , n.d.). Cities are encouraged to use these indicators as a benchmarking tool, to compare their score to other cities, and to get an overview of needed improvements. The set of indicators covers aspects from affordability and accessibility of the public transport system, to environmental emissions, as well as connectivity and overall satisfaction of the public.

As UAM will be operating within cities, the UAM system should be in line with the Sustainable Urban Mobility Plans and indicators developed by the commission, being also subject to evaluation against these metrics to ensure its sustainable implementation. To this end, an analysis of the applicability of SUMIs to UAM has been performed, defining the relation between the indicators and UAM, scoring the applicability from low to high. Table 1 provides an overview of this analysis.

Table 1 Applicability of SUMIs to UAM

SUMI Indicator	*Definition*	*Applicability*
Affordability of public transport for the poorest group	Share of the poorest quartile of the population's household budget required to hold public transport (PT) passes (unlimited monthly travel or equivalent) in the urban area of residence.	High
Accessibility of public transport for mobility-impaired groups indicator	This indicator determines the accessibility of public transport services to persons with reduced mobility.	High
Air pollutant emission indicator	Air pollutant emissions of all passenger and freight transport modes (exhaust and non-exhaust for PM2.5) in the urban area	High
Noise hindrance	Hindrance of population by noise generated through urban transport.	High

Road deaths	Road deaths by all transport accidents in the urban area on a yearly basis.	Medium
Access to mobility services	Share of population with appropriate access to mobility services in their area (public transport).	High
GHG Emissions	Well-to-wheels GHG emissions by all urban area passenger and freight transport modes	High
Congestion and delays	Delays in road traffic and in public transport	Medium
Energy efficiency	Total energy use by urban transport per passenger km and tonne km (annual average over all modes).	Medium
Opportunity for Active Mobility	Infrastructure for active mobility, namely walking and cycling	Low
Multimodal integration	The more modes available at an interchange, the higher the level of multimodal integration.	High
Satisfaction with public transport	The perceived satisfaction of using public transport.	Medium
Traffic safety active modes indicator	Fatalities of active modes users in traffic accidents in the city in relation to their exposure to traffic	High

An explanation for the assigned level of applicability per indicator is given here below:

- Affordability of the public transport system: at the moment, there is no indication of the initial prices of UAM. Given its novelty, the speculation is that the initial market prices for this kind of transport will not be affordable for everyone. This indicator is only applicable for the case of passenger transportation; other use cases, such as parcel deliveries or public (emergency) services, are not relevant for this indicator, but they are for UAM.
- Accessibility to the public transport system: the UAM vehicles for the transport of people are innovative and heterogenous in their design, with multiple concepts being developed. To the authors' knowledge, none of the design have taken into account the adaptability to transport people with reduced mobility.
- Air pollutant emission: even though many UAM vehicles are already designed to be electric, this should become a strict requirement for all vehicles.
- Noise hindrance: this indicator is already receiving a lot of attention from the industry. A lot of effort is being put for the design of quieter vehicles. However, noise hindrance should be considered also when designing the airspace structure and routes to be flown.
- Road deaths: even though this indicator refers to road traffic, it should be adopted by UAM as well, adapting it to airborne accidents.
- Access to mobility services: UAM should improve mobility in the city. Depending on the size of the city where UAM is implemented, the creation of routes to transport people across the city may be questionable. However, UAM could always be used as a resource to connect remote areas not reachable by public transport.
- GHG emissions: well-to-wheel emissions of UAM vehicles should be measured to ensure a true sustainable system. However, this should not only be adapted for use cases where passengers or freight are being transported, but also inspection and surveillance missions for instance.
- Congestion and delays: this indicator should be adapted to airborne traffic. In the case of UAM, delays over the estimated take-off and landing time should be measured. Moreover, a new indicator should be created, indicating the reduction in road traffic delays due to the use of UAM. This will help in measuring the added value of UAM to society.
- Energy efficiency: this indicator should be adapted to include renewable sourcing of energy. Overall, UAM should aim to be as energy efficient as possible, designing routes and hubs to optimize this aspect.
- Opportunity for active mobility: this indicator does not apply to UAM, as it is more focused on city planning.
- Satisfaction with public transport: for UAM to succeed, the system should be satisfactory for the public, focusing on the easiness of use and on the benefit by the public. This indicator should be applicable to all use cases, looking not only at the satisfaction in terms of transport of people, but also freight transport and public services.
- Traffic safety active mode: UAM follows the same safety standards as aviation, which are higher than road traffic. Nevertheless, fatalities should also be measured, which will require this indicator to include also airborne traffic fatalities in the city.

Except for the indicator "Opportunity for Active Mobility", all indicators are highly applicable to UAM, either in their current definition, or with the need of adaptation to airborne traffic. Moreover, the indicators provide an overview of gaps in the sustainability of the UAM system. For instance, policies should be implemented to ensure the affordability of UAM transport; vehicle design should be adapted to ensure accessibility to passengers with limited mobility; and route and airspace structuring should be designed to minimize noise hindrance.

Overall, the inclusion of UAM in the SUMIs would be highly valuable. However, as the indicators have been developed to measure the sustainability of public transport, they could be limited to the UAM use cases of passenger transport. In the future, the indicators shall be adapted to cover the broader variety of UAM use cases (e.g. surveillance, inspection, cargo, or medical missions). Moreover, it would be advisable to include the following adaptations or additions in order to fully cover UAM:

- Improved connectivity in cities: the indicator shall measure the share of population living in remote areas with improved connectivity to the city thanks to UAM.
- UAM time efficiency: share of UAM operations to be carried out to reduce road traffic. This may give an indication of the needed (if any) UAM services to be implemented to reduce road traffic congestion.
- UAM traffic deaths: UAM traffic accidents on a yearly basis.
- GHG emissions: include well-to-wheel emissions of all relevant UAM use cases, not only passenger or freight transport.
- Privacy concerns: share of complaints received from citizens about privacy issues.

4. Experts' opinion

To compliment the literature review, a series of interviews with experts from different backgrounds in the field of UAM were carried out. Experts from research centres, academia and industry, were interviewed. The following questions were used as a baseline to conduct all interviews:

1. What meaning do you, as expert in UAM, give to the word "sustainability"?
2. What do you perceive, as expert in UAM, is the meaning given to the word "sustainability" in the UAM industry?
3. What do you think society expects from a "sustainable UAM"?
4. What do you see as potentially the larger disconnect between society's expectations of "sustainability" and the industry's ambitions?
5. How high is the risk of greenwashing when talking about UAM?
6. Do you see UAM going forward even if sustainability is not reached?
7. What measures should be implemented to ensure that UAM is truly sustainable?
8. Where do you see gaps that difficult the sustainable implementation of UAM?

All experts expressed a similar definition of sustainability: a wide concept that covers environmental sustainability, as well as economic and societal sustainability. This means that, regarding sustainability in UAM, all aspects of the concept should be addressed: the whole life cycle of the product, (production, operation, end-of-life), charging infrastructure (powered by renewable energy), the business case, and the integration in society, ensuring accessibility and added value to society.

When talking about the views of the industry on the meaning of "sustainable UAM", the general opinion was that there is a tendency in the industry to focus only on emissions, while UAM can only be sustainable when the whole system is addressed. Because of this misappropriation of the definition, there is a big risk of the industry greenwashing the concept of UAM.

Furthermore, there was a shared opinion about the lack of awareness of the public regarding what sustainability means in its full extent. If the public is not educated about sustainability, there is a risk of creating the idea that UAM is sustainable for the sole reason of being powered by electricity.

Overall, the following take-aways were extracted from the interviews:

- LCA should be carried out to benchmark UAM against other modes of transport and to have a real understanding of sustainability gains or losses.
- Energy requirements should be defined to ensure that the system is sustainable as a whole. Energy efficiency should be maximised, and vehicles should be powered only by renewable energy.
- UAM should favour multimodality, complementing other modes of transport instead of competing against them.
- UAM business models have to be sustainable, with the aim of creating benefits for society and businesses.

- There is a risk of technology development winning over sustainability. However, future iterations of the technology may become sustainable in the end.

All in all, the interviews revealed that there is a misappropriation of the term "sustainability", leading to a risk of greenwashing the concept of UAM. To go forward, the full life cycle of the product should be taken into account, and the economic and social sustainability of the system should be looked into, making sure that UAM is not only technological sustainable, but also something that responds to the needs to people and businesses and that creates positive impact for the society.

5. Discussion and conclusion

Literature and industry tend to dive into the topic of UAM without addressing sustainability aspects. If anything, a mention is made about how a product or system is sustainable without really explaining how this sustainability is achieved. Only in some cases an explanation is given about how the challenge is tackled, and in even fewer cases a full critical analysis is performed.

The literature review showed that sustainability in UAM is in fact a research gap, with only a few papers addressing the topic. Generally, no environmental considerations are taken into account when discussing the design of vehicles and vertiports. For the former, a mention to circularity and modularity is made in some cases, but sustainable design guidelines are disregarded. In the case of vertiports, most industry players state that sustainability is taken into consideration in the design of their vertiport, but no explanation is given about how this is done. Local and sustainable materials are mentioned in architectural design papers, also highlighting the need for the vertiport to be a multifunctional building that creates a positive impact in society. Like in the case of vehicles, modularity and design for adaptability are important to ensure the durability and environmental sustainability of the vertiport.

Regarding the topic of operations, most literature focuses on the design of concept of operations and airspace structure that provide a safe framework for UAS to fly within, analysing the heterogeneity of vehicles and separation management. Even though safety is a critical aspect and should always be addressed when designing operations, it is not the only aspect that should be taken into account. An initial proposal was made by the SESAR JU project CORUS-XUAM (2022) about sustainable aspects to be considered when designing operations, such as the location of the vertiports to optimise routes, or design of optimised arrival and departure operations. Vehicle design will ultimately have an impact in the sustainability of operations as well, with the distributed-propulsion design providing the best results in terms of energy efficiency and noise reduction.

In general, the lack of a definition for what it should be understood by sustainability in UAM leads to vague statements and misappropriation of the word. To quote Tom Bosschaert, sustainability is "the state of a complex dynamic system…which means that sustainability is the property of a society or of a system, it is not the property of an object, so you can't say this building is sustainable because it doesn't mean anything… [sustainability] is a relational property between things, so how things work together in a dynamic way creates a position where all those things, people, plants, trees, cars, whatever work together in a sustainable way or not". As such, sustainability in UAM should not only be understood as environmental sustainability, but also social and economic sustainability. This means that, for UAM to be sustainable, it should create a system which delivers an overall positive impact: the vehicles and infrastructure should be environmentally sustainable from design and production to end of life; the use of the system should deliver value to the end user and be available for all; and the business case should be sustainable, economically as being affordable, while supporting long-term economic growth without negatively impacting social and environmental aspects of the communities.

Going forward in the implementation of UAM, there are a number of aspects that should receive attention to create a system that is truly sustainable:

- UAM should facilitate multimodality, complimenting other modes of transport when appropriate;
- A set of specific indicators should be developed to compliment the SUMIs, giving stakeholders the appropriate tools to assess the sustainability of UAM;
- Deployment of UAM service should be based on sustainability assessments, starting with LCA, to critically compare gains and losses created through UAM and those of other modes of transport;
- In the concept of operations, social, environmental and economic sustainability should be included.

In light of the above, and given the current need for solutions with limited or no impact to the environment, any new technology introduced in society should prove to be sustainable from the start, in the broad sense highlighted. Currently, the UAM ecosystem is focused on the technological feasibility and safety of its solutions. For UAM to be an impactful and green solution for mobility and transport, it will have to comply with a series of sustainable requirements defined by the authorities and endorsed by society. Such sustainable requirements shall include environmental, social and economic sustainability. Those will enable the deployment of truly sustainable solutions for UAM, with environmentally sustainable vehicles and infrastructure throughout their full life-cycle, providing services that benefit users, while, at the same time, creating a positive impact for the society.

Acknowledgments

We thank the European Aviation Safety Agency (EASA), TU Delft University, Łukasiewicz Research Network – Institute of Aviation (Łukasiewicz – ILOT), and National Aeronautics and Space Administration (NASA) for their support to write this paper and contribution with their opinions about the status of sustainability in UAM.

References

Bayards, n.d. Sustainability. [Online] Available at https://www.bayardsvertiports.com/solutions/sustainability

Blevis, E., Preist, C., Schien, D. & Ho, P., 2017. Further Connecting Sustainable Interaction Design with Sustainable Digital Infrastructure Design. s.l., LIMITS .

BMW, n.d. The BMW Vision is Circular. [Online].

Çetin, E. et al., 2022. Implementing Mitigations for Improving Societal Acceptance of Urban Air Mobility, s.l.: s.n.

EASA, 2021. Study on the Societal Acceptance of Urban Air Mobility in Europe, s.l.: s.n.

eHang, 2021. EHang Partners with Giancarlo Zema Design Group to Build Eco-Sustainable Vertiport in Italy. [Online] Available at: https://www.ehang.com/news/746.html

European Commission , n.d. Sustainable Urban Mobility Indicators. [Online] Available at: https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/sumi_en

Karolin Schweiger, F. K. B. K., 2021. An exemplary definition of a vertidrome's airside concept of operations, s.l.: s.n.

Kasardaa, M. E. et al., 2007. Design for adaptability (DFAD)—a new concept for achieving sustainable design, s.l.: s.n.

Kasliwal, A. et al., 2019. Role of flying cars in sustainable mobility, s.l.: Nature Communications.

Lilium, 2020. Designning a scalable vertiport. [Online] Available at: https://lilium.com/newsroom-detail/designing-a-scalable-vertiport

McGill University , n.d. What is sustainability?, s.l.: s.n.

Moraga, G. et al., 2019. Circular economy indicators: What do they measure?. Resources, Conservation & Recycling, Issue 146, p. 452–461.

Renault Group, 2017. Renault and powervault give EV Batteries a Second Life in Smart Energy Deal. [Online].

S&P Global , 2019. The ESG Risk Atlas: Sector And Regional Rationales and Scores, s.l.: s.n.

Skyports, Wisk, 2022. Concept of Operations: Autonomous UAM Aircraft Operations and Vertiport Integration, s.l.: s.n.

The Vertical Flight Society , 2022. Press Release: VFS Electric VTOL Directory Hits 600 Concepts. [Online] Available at: https://vtol.org/news/press-release-vfs-electric-vtol-directory-hits-600-concepts

Venice Biennale - L'architecture d'aujourd'hui, 2016. The Droneport Project, s.l.: s.n.

World Commission on Environment and Development's , 1987 . Brundtland Report "Our Common Future", s.l.: s.n.