REPORT

UNLOCKING NEW ROUTES IN AFRICA WITH E-FLIGHT

AUTHORS:

Christine Driessen | Lindokuhle Tshuma | Marcel Langeslag

September
2022

NACO
a company of Royal HaskoningDHV

NACO
a company of Royal HaskoningDHV

Table of CONTENTS

01.

Introduction

This report contains an exploration of the potential of electric flight – through the findings of a recent case study by NACO that was presented at the 2022 AviaDev Africa conference in Cape Town, South Africa. The study outlines the considerations for the implementation of electric flight in general and zooms in on possible routes in the Southern Africa region. It aims to show the potential this new technology could offer for enhancing connectivity and to spark further debate on the topic.

Africa is a vast continent, covering more than 30 million square kilometres, with a relatively low density of road and rail infrastructure. Air transport is ideally suited to provide connectivity between cities, regions and countries that cannot otherwise be connected in a timely manner, enabling the flow of goods and people that drive economic activity. Africa's 1.4 billion people represent almost 18% of the global population – it is the youngest population, with a median age of 18, and the fastest growing in the world. The continent offers an enormous potential market for aviation.

However, up to now this potential has not fully materialised as Africa represents only 3% of global passenger traffic. A wide range of issues - from relatively low income levels and a lack of infrastructure to high operating costs and a restrictive regulatory environment - has hampered the growth of air travel seen in other regions. This has resulted in low connectivity and the highest airfares in the world.[1]

Increasing air services on the continent is a priority of the African Union (AU), embodied in the Single African Air Transport Market (SAATM) initiative. It has the potential to enhance and support a wide range of activities that improve the quality of life and contribute significantly to both the AU's Agenda 2063 and the UN's Sustainable Development Goals. It is within this context that we explore the potential that new technologies have to offer to enhance sustainable connectivity on the continent.

https://youtu.be/CmFEEODUfiE

02.

Sustainability

The drive for sustainability is underway in aviation – powered not only by the need for more sustainable airport operations in the face of global Net Zero targets, but also the opportunities that sustainable solutions could present for airports, airlines and passengers alike.

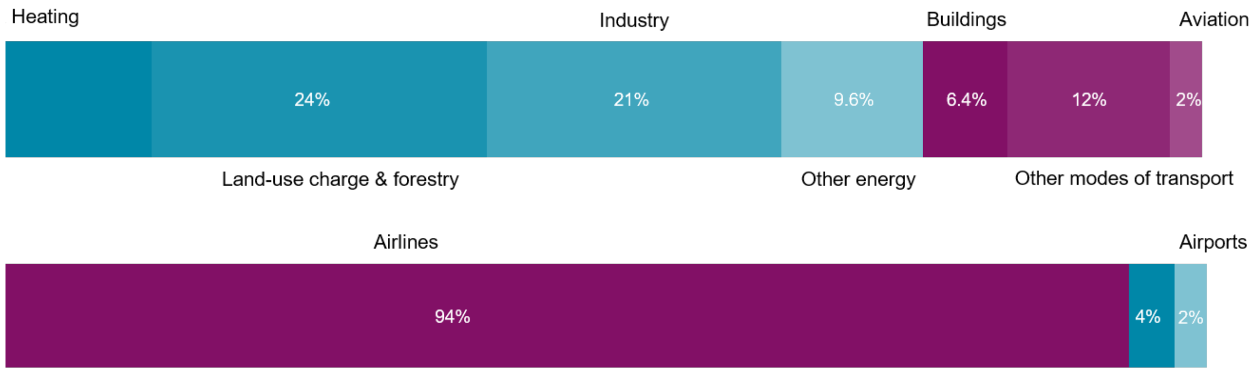


Figure 1: Global Greenhouse Gas Emissions Per Industry and Broken Down for Aviation

The picture is clear – aviation represents approximately 2% of global CO_2 emissions, which results in an amount of over 1 billion tons in 2019. To put this into perspective, South Africa emitted 555 million tons in 2019 which means the aviation emissions represent almost twice the CO_2 emissions of South Africa in that year [2]. Important to note is that 94% of those emissions are caused by airline operations – in other words, aircraft burning fossil fuel.

In response, several countries have pledged to push for sustainability in aviation, with a focus on three key solutions: sustainable aviation fuels (SAF), hybrid/electric planes and hydrogen powered planes. Each of these solutions has its own benefits and challenges and may be applicable in different circumstances. For instance, SAF and hydrogen can be used for larger aircraft and from short up to long haul routes, even though hydrogen may present range limitations due to high space demand due to the larger volume requirements of hydrogen. Electric aviation is most suitable for small aircraft and short routes due to limitations on battery energy density.

This study focuses on electric powered aircraft as it has the potential to address some of the challenges currently facing aviation in Africa. Low demand and high costs often lead to so-called thin routes that are not financially viable for conventional airlines with large aircraft. A lack of airport infrastructure in many secondary cities, let alone remote regions, means many available runways are short and not suitable for large jet aircraft. Finally, the availability and cost of aviation fuel often presents challenges to flight operations outside of the main route networks. Electric flight may provide a sustainable solution to these challenges, offering enhanced connectivity on the continent.

Image source: www.eviation.co/

03.
Electric Aircraft

The figure on the following page shows the range of electric aircraft that are currently being developed. The Pipistrel Velis Electro, first from the left, is the only EASA certified fully electric aircraft flying at the time of writing. It can fly up to 50 minutes while taking into account the necessary battery reserves for visual flight rules operations (around 30% of the state of charge). There are also conversion kits available that enable small conventional aircraft to be converted to battery power.

The first batch of all-electric aircraft expected in the coming five years are limited to less than 10 seats and a (catalogue) range of less than 800km or 440nm. This also includes several electric vertical take-off and landing (eVTOL) aircraft focused on the urban air mobility (UAM) market. Several hybrid aircraft, combining conventional fuel engines and electromotors, are also anticipated in this bracket.

The next batch of aircraft, projected to come onto the market between 2026 and 2030, will push the envelop to as many as 19 seats and with similar range as the smaller precedents. Interestingly, most of the aircraft up to this point are being developed by start-up or small manufacturers. Some of the established original equipment manufacturers (OEM) are working on developments of their own. Embraer's Energia range of sustainable aircraft includes hybrid, full electric and hydrogen-powered concepts. Boeing's SUGAR Volt hybrid electric aircraft is anticipated in the 2030 to 2050 timeframe. Finally, while Airbus developed successful testing models like the E-Fan X and EcoPulse, it has not yet announced definitive plans for bringing electric or hybrid aircraft to the market. Airbus does focus on three different hydrogen powered aircraft models, a turboprop, a turbofan and a blended-wing model.[3] The range that electric aircraft will be able to fly depends on a balance between weight and battery capacity. Adding more batteries to increase the range, also increases the weight of an aircraft, thereby reducing its seat (or payload) capacity. Every manufacturer is striving to find the optimal balance between capacity and range, given the available battery technology. As the energy density of batteries increases, it will become possible to get more miles out of the same empty weight or reduce the empty weight and add more seats and increase payload.

The opportunities presented by these new aircraft is attracting serious interest from airlines and leasing companies who intend on making aviation more sustainable. United Airlines, Cape Air, DHL and Amedeo have placed orders or signed letters of intent to do so, for a total of at least 400 electric aircraft (excluding the eVTOL market segment). It is evident that manufacturers, investors and airlines all see the potential of this technology to play a major role in future aviation services offering.

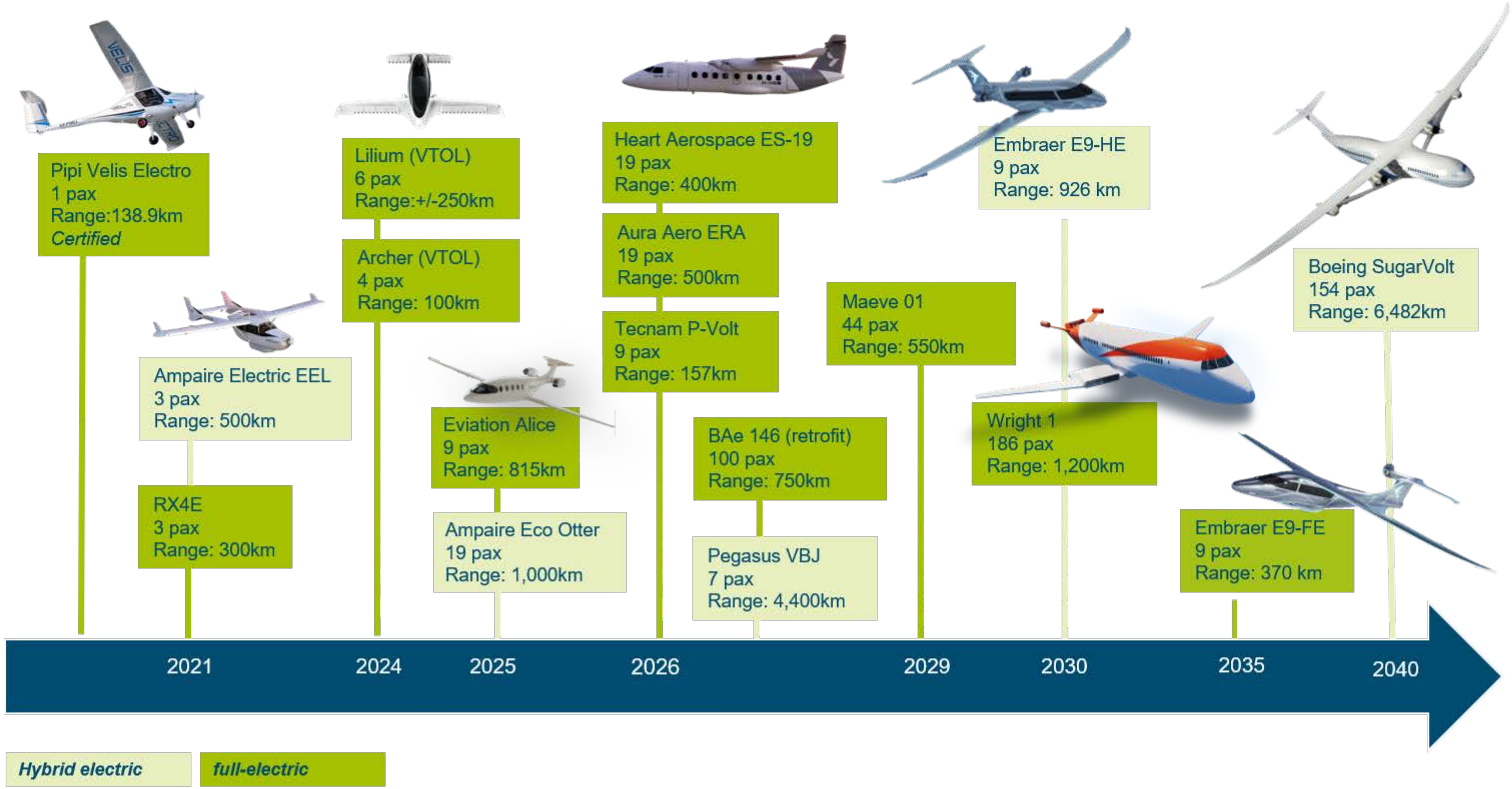


Figure 2: The rich palette of e-aircraft expected on the market up to 2040 (source Roadmap electric flight NACO & NLR)

04. Technological Developments Driving Electric Aviation

The emergence of electric flight as a viable solution to address challenges in sustainability and connectivity is driven by several technological developments. While the technology available today can only take us so far, innovations are taking place that promise to improve the situation considerably in the coming years. Issues like battery weight (and the resulting flight range) and standardisation of equipment and protocols are being worked on by established players as well as new entrants into the market. The technological advancements in this field were investigated in 2019 during a study prepared for the Dutch Ministry of Infrastructure together with the Netherlands Aerospace Centre NLR. The findings have been incorporated in this section.

4.1 Energy Density

Currently, lithium-ion (li-ion) batteries are most commonly used by OEM for electric aircraft. They have one of the best energy-to-weight ratios compared to the various battery chemistries, but it is still 50 times lower than kerosene. This means the energy density is only sufficient for small aircraft with limited range. However, ongoing developments in battery technology show a clear trend towards improved performance (see 3). In fact, the energy density of battery cells, measured in Watt-hour per kilogram (Wh/kg) have almost tripled since 2010, from 100 to 300 Wh/kg [4]. Although the current energy density is not the ideal case, it is a fruitful start to the maturity of battery systems offering hope for future clean skies.

Battery manufacturers involved in developing batteries for electric flying are aiming to reach an energy density of 400 Wh/kg in the next 5 years. Scientific studies show that even specific energies in excess of 600 Wh/kg may be feasible by 2030 [5]. Such battery energy densities would support electric flying with a range of up to 500 km[6] . Beyond this, alternative battery chemistries, such as solid state and graphene, are under development that could provide a further leap in energy density.

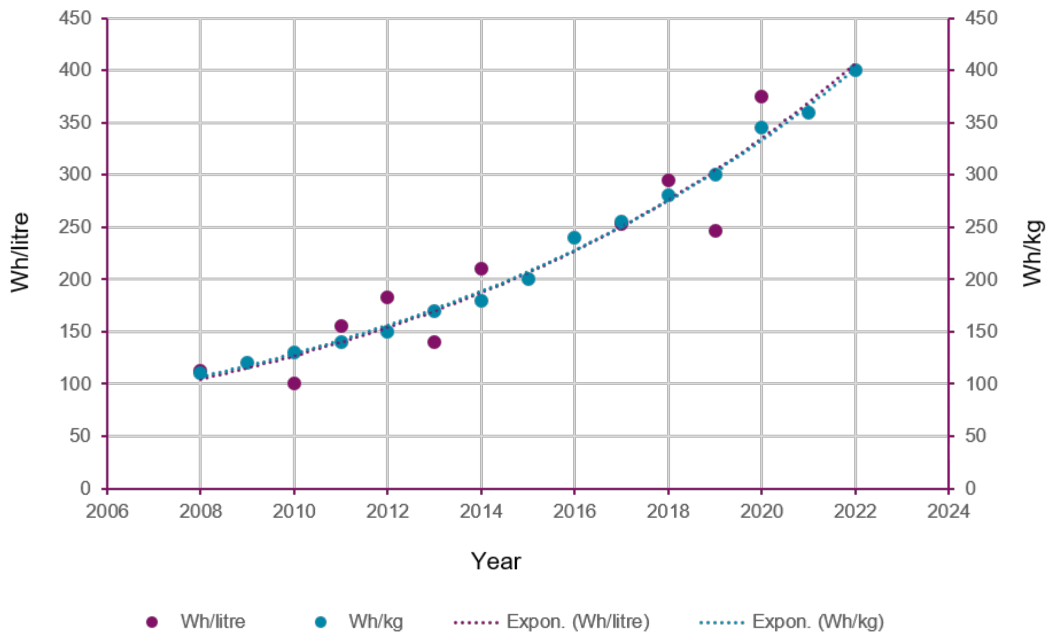


Figure 3: Li-ion battery-specific energy and volumetric energy density [a] [b] [c]

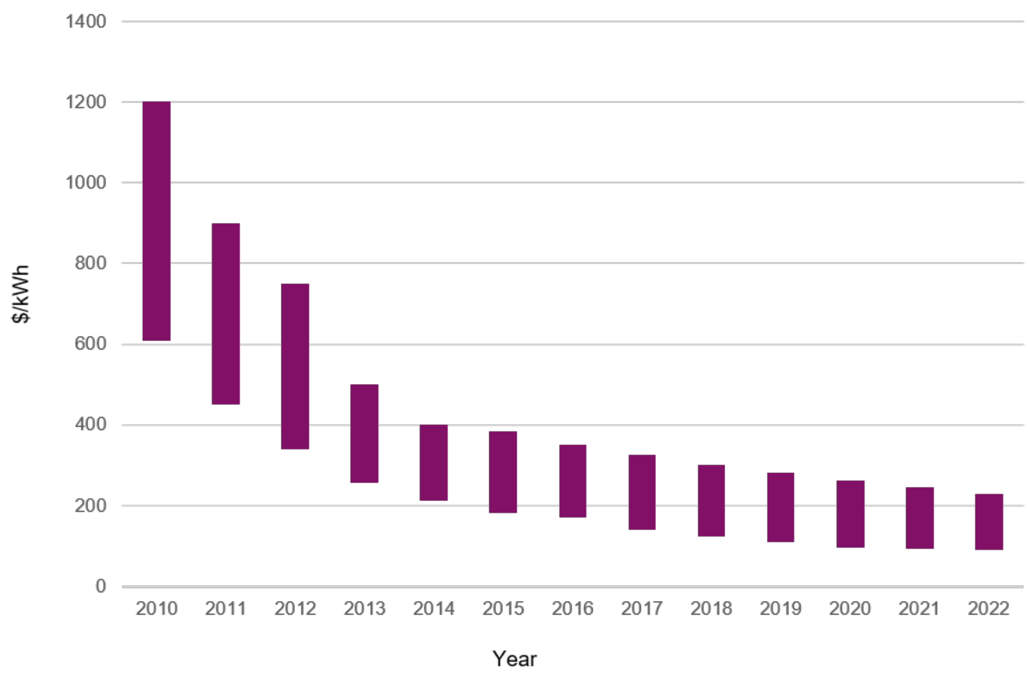


Figure 4: Li-ion battery costs [c] [d] [e]

4.2 Battery Costs

Along with the growth in energy density, the demand for li-ion batteries has boomed over the past decade or so, driven mainly by the market for electric cars. Bloomberg New Energy Finance (BNEF) estimates that the global market for Li-ion batteries will grow from less than USD 40 billion today to around USD 120 billion in 2030 [7]. At the same time, the prices of these batteries are falling rapidly, reporting a drop of 87% from 2010 to 2019. As depicted by the trends in 3 and Figure 4, the increase in energy density and the decrease in battery costs presents benefits along both environmental and economic lines. The use of batteries in long-range aircraft might be far from reach, but there is, great potential for the short-haul market with electric aircrafts that are efficient carbon and cost-wise.

4.3 Charging Infrastructure

Charging technology is also under continuous development, in line with the widespread adoption of electric cars. Currently, for automotive applications there are fast chargers providing 350 kW and for heavy duty vehicles experiments have been carried out with systems up to 3.75 MW. This is important as charging electric aircraft needs to be done swiftly in order to be competitive with regular turnaround times of small sized aircraft of around 30 minutes.

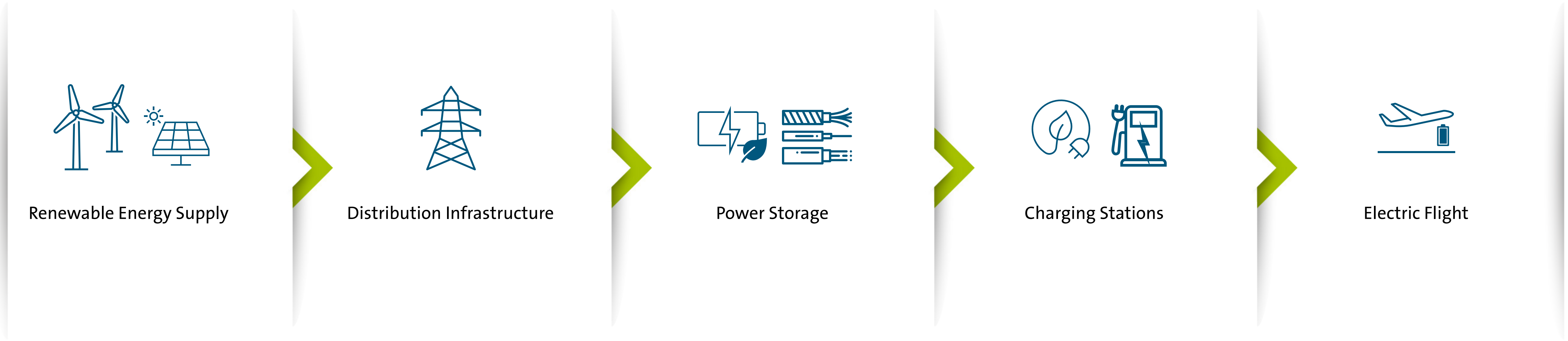
Electric aircraft manufacturer Heart Aerospace stated that its ES-19 electric aircraft model will require a 1MW charger to be able to charge in less than 40 minutes. The first certified electric aircraft, the Pipi Velis Electro has its own charging infrastructure. The 24.8 kWh batteries of the aircraft can be charged with a compatible 20 kW charging station with an operating voltage of 400 Volt. The charging time is around 1 hour and 20 minutes to charge a normal cycle which is from 30% to 95% [8]. An alternative approach to battery charging is to swap out depleted batteries for fully charged ones during turnaround. It is an attractive approach that is already applied successfully in a range of applications from electric scooters to drones. However, it requires more batteries and may present challenges in terms of flight safety certification, as the battery swapping may be considered a maintenance activity.

Another important consideration is the standardization of charging technology and protocols. In order for electric aviation to be scaled up and become widely accepted, automation of charging processes and implementation of safety measures will prove vital.

4.4 Renewable Energy Supply

The remaining piece of the hardware puzzle is of course the supply of energy for the charging of aircraft batteries. For electric flight to be a sustainable solution, the energy would have to be derived from renewable sources. For many airports in Africa, the most likely sources will be solar (PV) panels or wind turbines. As these energy sources provide intermittent supply, energy storage facilities will be required to assure continuous supply. Moreover, fast charging of batteries will result in high demands and during peak hours multiple aircraft may have to be charged simultaneously. Therefore, the local energy grid should be stable and robust. This means specialised infrastructure for energy generation, storage and distribution will be indispensable.

The need for such infrastructure poses questions around the investment, ownership and operations. Multiple stakeholders may be involved, or one party can take control of the entire chain, effectively becoming an energy supplier and aircraft ground handler in one. It presents opportunities for new operating models, revenue streams and business propositions.



05.
Benefits of Electric Aircraft

Provided the energy to charge batteries is generated from renewable sources, electric aircraft generate no greenhouse gas emissions during operations. As they make no use of fuel combustion, electromotors do not cause particulate pollution either. Moreover, they operate much more quietly, lowering the noise footprint of aviation significantly.

We have seen that electric aviation is mostly geared towards small aircraft and short distances. Conventional wisdom tells us that small aircraft have high operating costs per seat, especially on short distances. However, the economics of electric aircraft may turn out to be quite different.

The operating costs of an electric aircraft compared to the same size conventional aircraft is considerably lower. This is related to the price of kerosene per kilometre flown compared to the price of (renewable) electricity. According to Heart Aerospace, this reduces operating costs by around 50% to 70%, depending on electricity and fuel prices at a specific location. For example, for a flight in Sweden of approximately one hour the electricity cost compared to the conventional fuel cost was 6.5 times lower[9]. Looking at the current situation with jet fuel prices rising and potentially subject to future emissions-related charges, electricity as source of energy is only become more and more favourable. Ultimately, the price of energy will depend on the generating technology, factors of scale and costs of financing.

In addition to operating costs, the maintenance cost of e-aircraft will also be lower compared to similar-size conventional aircraft. This is mainly due to the engine type used for electric powered aircraft which has a much smaller number of moving parts and the time between maintenance of the motor is much longer than that of a piston or jet engine. Estimations of the maintenance costs for the Pipistrel aircraft showed the cost of the electric 2-seater to be around 40 to 45% lower than the maintenance cost of a conventional aircraft of the same size.

Finally, airport taxes are also expected to be reduced due to the sustainable solution e-flight offers. No carbon offset will be required anymore, and airport taxes are expected to be favourable compared to the taxes for conventional aircraft. For example, in 2021 the Netherlands implemented an aviation tax per passenger that is applied for each passenger that departs from a Dutch airport, in order address the contribution of aviation to global greenhouse gas emissions. The charge is currently around €8 per passenger and is predicted to triple by 2023. A zero-emissions solution such as electric flight will not be subjected to such fees. [10] [11] [12]

06.

Enhancing Connectivity in Southern Africa

The pursuit of transforming and expanding commercial aviation has become a priority in connecting cities across Southern Africa through lucrative and sustainable routes. We developed a methodology to identify routes in the region that have the potential to be operated with e-aircraft. The countries in the Southern African Customs Union (SACU), namely Botswana, Lesotho, Namibia, South Africa, and Eswatini, have agreed to preferential aeronautical tariffs, facilitating regional air travel. Therefore, this region forms a natural case study environment. Figure 5 shows the selected airports included in this study, with the capital airports shown in red, the large green dots representing main hubs and small green dots the regional airports.

The initial aim was to look into the potential replacement of existing routes, and subsequently to evaluate the potential new routes between the main hubs and the regional airports and between regional airports. This was done for two range categories, one of less than 300km and another category of routes less than 600km. These categories correspond to the feasible effective range the electric aircraft are expected to reach in the next 5 years for the first category and in the next 10 to 15 years for the second.

In order to identify the existing routes that could be served with e-aircraft, we analysed the routes that are being operated either on a low frequency with large aircraft, or on a high frequency with small aircraft. Figure 6 indicates the routes that at the moment receive a weekly service at most, with aircraft that have a seating capacity over 19. In these instances, the service quality could be enhanced by operating a smaller e-aircraft with a higher frequency. For example, a once-weekly service with a 120-seater, could be replaced by a daily service with a 19-seater. This will benefit passengers by introducing flexibility in the availability of flights and those in need of urgent flights

Figure 7 shows the routes that currently receive regular service with small aircraft with fewer than 19 seats. On these routes, the aircraft can simply be replaced with the applicable e-aircraft.The following figures show the new routes between the selected airports that can be operated with e-aircraft. The routes shown in Figure 8 and Figure 9 follow the conventional hub-and-spoke model, where flights are operated from large hub airports into smaller spoke airports. Operating e-aircraft on these routes would make it possible to link secondary destinations and outlying regions to economic centres in a cost-effective manner. Within the study sample, a total 69 of such possible routes have been identified.

Given the new economics of e-aircraft discussed earlier in this report, a new approach of point-to-point connectivity between regional airports also becomes a real possibility. Figure 10 and Figure 11 indicate the direct routes between the smaller airports in the sample that could be opened up with e-flight. With an effective flight range of 300km, we identified 32 of these routes, which can grow up to an impressive 73 new routes when the effective range is extended to 600km. These numbers highlight the potential that e-flight offers for enhanced connectivity on thin markets in the Southern Africa region.

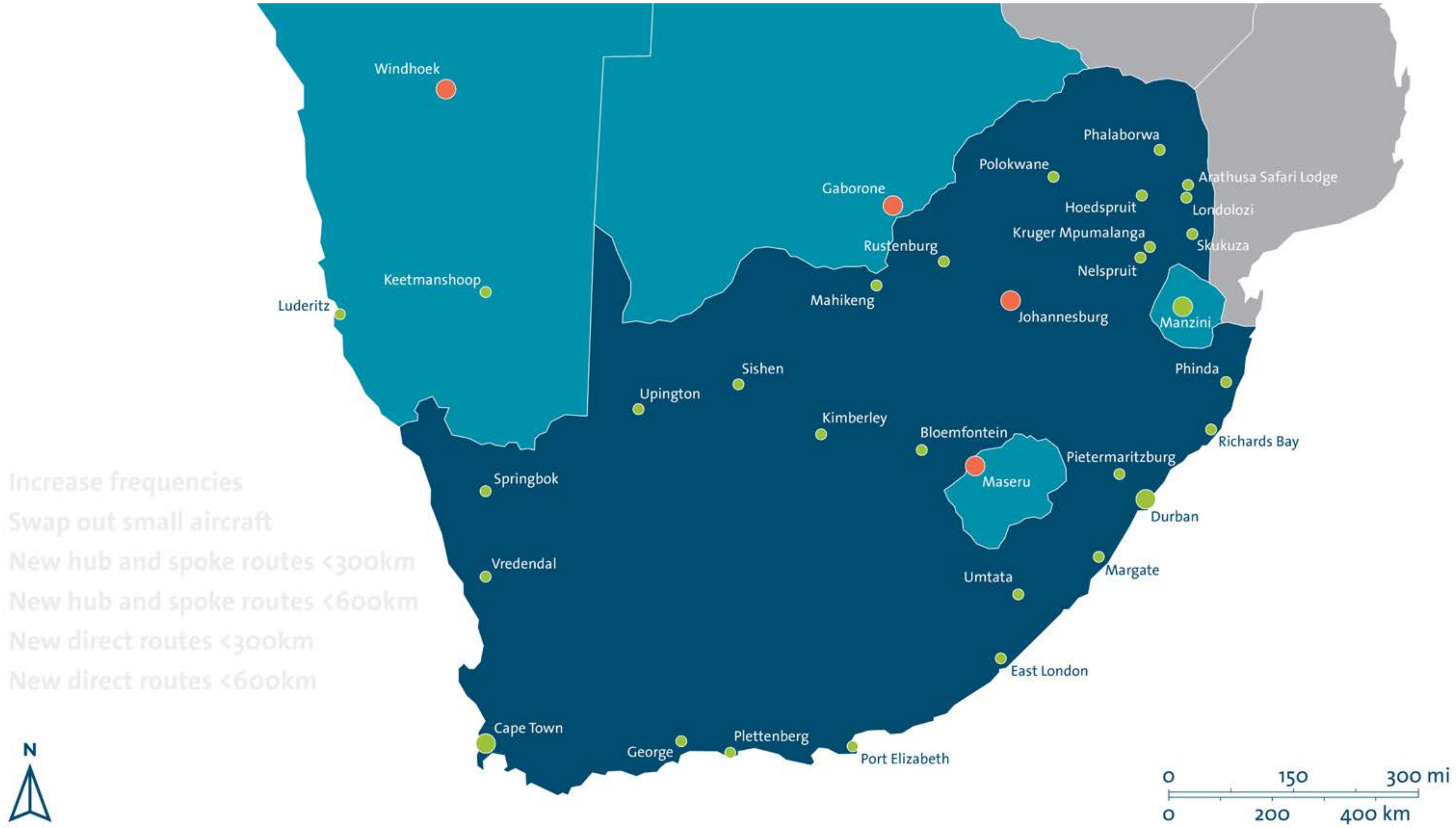


Figure 5: Selected airports for the study

Figure 6: Routes with at most a weekly service by aircraft with a seat capacity over 19

Figure 7: Routes with frequent service by aircraft with a seat capacity below 19

This case study demonstrates the potential of serving existing routes with e-flight and the even greater impact it could have in creating new routes. A total of 174 routes that could be served with future e-aircraft in the region have been identified. The technological advancements will drive the technical feasibility of operating electrically powered aircraft on these routes. The remaining important factor is now to determine the demand for air travel on those routes, at the cost structure of e-flight, in order to develop profitable business cases.

Figure 8: New hub and spoke routes up to 300km

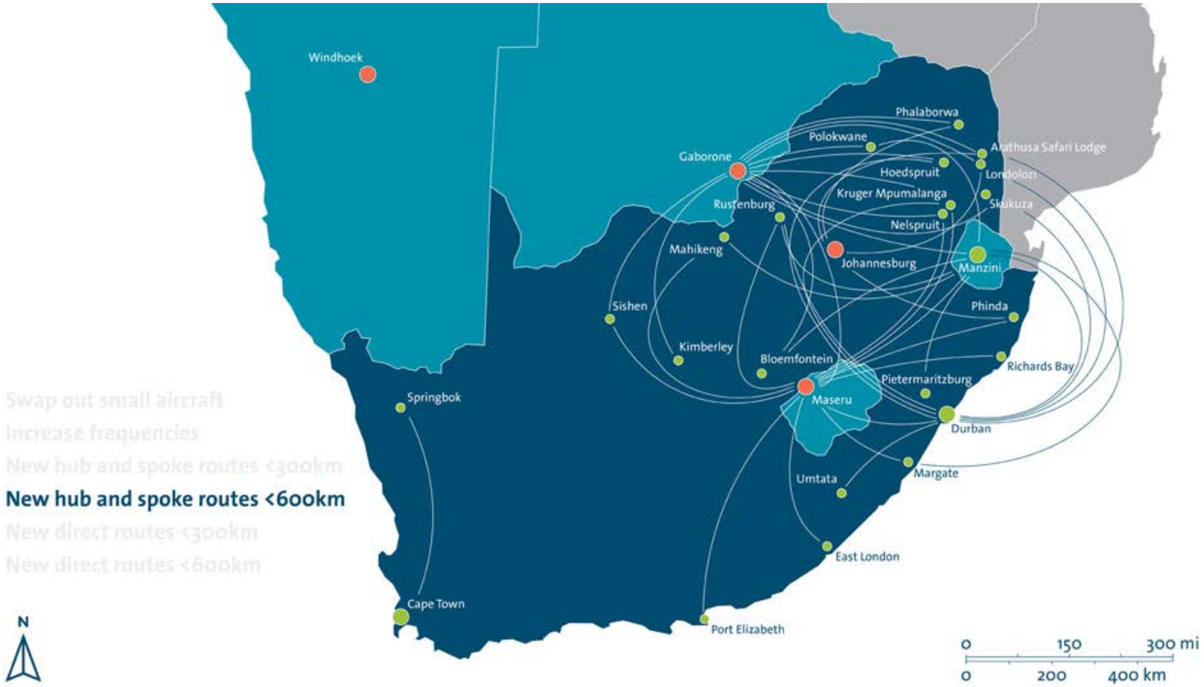


Figure 9: New hub and spoke routes between 300km and 600km

Figure 10: New point to point routes below 300km

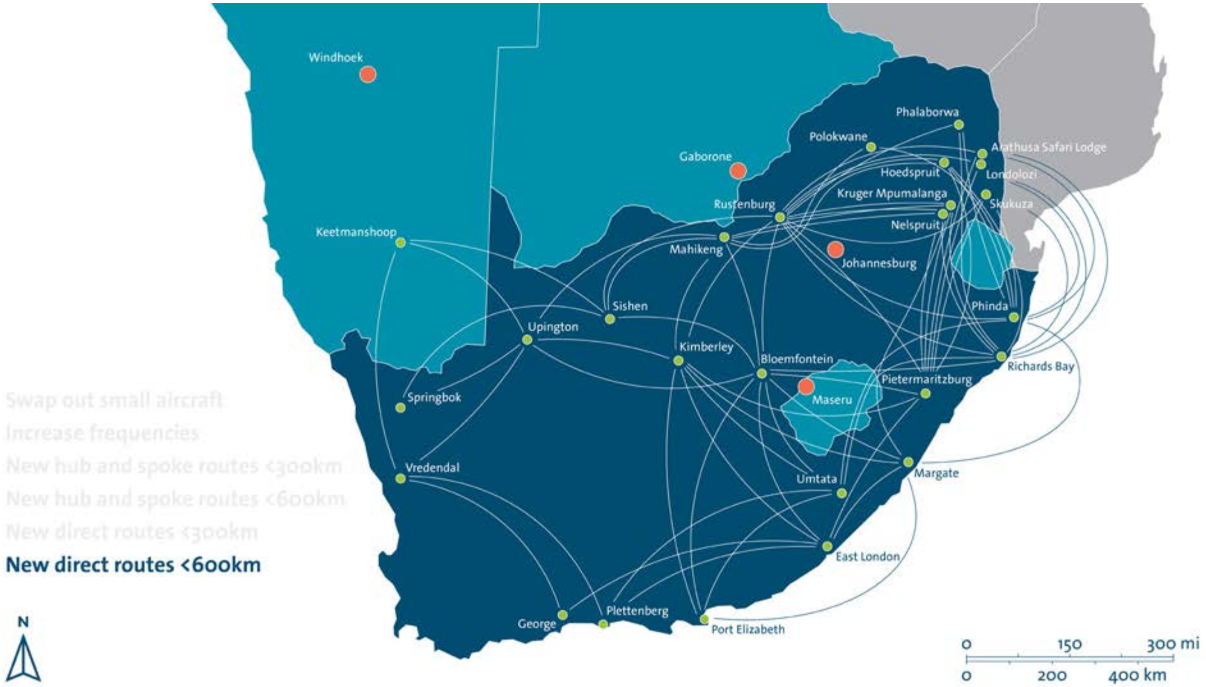


Figure 11: New point to point routes between 300km and 600km

07. Implementation Requires Collaboration

Collaboration is very important as the implementation of electric flying involves many stakeholders, who will have to exchange information in order to be able to act together. Important to note is that the actions of the different stakeholders will sometimes have to run in parallel, and several actions depend on the completion of another one.

In addition, to enhance the implementation of electric flight, challenges must be addressed such as timely certification of aircraft, training of pilots and technical staff, robust renewable energy infrastructure, the set-up of profitable business cases to fly electric and the upscaling of the production of the new designs by mostly start-up OEMs. Regulators and authorities are expected to create an enabling environment for the transition, including specific technical and economic regulations to suit e-flight. Next to these implementation challenges, it is also important to consider the use of raw materials in the production of electric aircraft batteries, as well as the end-of-life solutions for batteries and composite aircraft. This is crucial to make sure the full life cycle of the electric aircraft is sustainable by making sure all parts can be recycled or disposed of safely.

Finally, particularly in the light of the ever-evolving technological developments such as batteries as mentioned before, it is strongly advised to periodically revisit and review e-flight resources, assets, processes, and operations to identify and act upon optimization areas during and after implementation.

Manufacturers E-aircraft Batteries Chargers	**Authorities & Associations** ICAO EASA, CAA IATA, ACI, CANSO	**Air Navigation Service** Providers ATNS ASECNA	**Airlines** Investors & Lessors Aircraft Staff
Airports Infrastructure Operations Maintenance Repair & Overhaul	**Energy provider** Local supplier Airport handler	**Educational institutes** Universities Staff training institutes	**Government** Regulation Taxation Incentives

08.

Preparing the Airports of Today, for the Aviation of Tomorrow

In the journeys towards enhanced connectivity in Africa and Net Zero aviation, implementation of e-flight is gaining ground. Its benefits go beyond the ambit of environment, extending into the socio-economic and contributing to improved quality of life. This study has demonstrated the enormous potential it offers for unlocking new routes in the Southern Africa region and provides a glimpse of what may be possible in the rest of the continent.

At NACO we understand that there isn't a single solution to enhanced connectivity and more sustainable aviation. From enabling the implementation of the Single African Air Transport Market, to supporting sustainable airport development across the continent, the team at NACO is pioneering to shape the next generation of aviation. Together with our clients and partners we are at the forefront of sustainable aviation.

References

1 **Kincaid, Ian. Saatmbenefits.** [Online] 2021. https://www.saatmbenefits.org/saatm/wp-content/uploads/bsk-pdf-manager/2021/08/Continental_Study.pdf).

2 **Mengpin Ge, Johannes Friedrich, Leandro Vigna.** [Online] 2020. https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors.

3 **Airbus.** [Online] https://www.airbus.com/en/innovation/zero-emission/hydrogen/zeroe.

4 **Field, Kyle. CleanTechnica. [Online]** 2020. (https://cleantechnica.com/2020/02/19/bloombergnef-lithium-ion-battery-cell-densities-have-almost-tripled-since-2010/.

5 **Venkatasubramanian Viswanathan, Alan H. Epstein, Yet-Ming Chiang, Esther Takeuchi, Marty Bradley, John Langford & Michael Winter.** [Online] 2022. https://www.nature.com/articles/s41586-021-04139-1.

6 **Graver, Jayant Mukhopadhaya, Brandon.** [Online] 2022. https://theicct.org/publication/global-aviation-performance-analysis-regional-electric-aircraft-jul22/

7 **Halvorson, Bengt. Green Car Reports.** [Online] 2019. Electric-car battery prices dropped 13% in 2019, will reach $100/kwh in 2023 (greencarreports.com).

8 **Pipistrel Aicraft.** [Online] https://www.pipistrel-aircraft.com/products/general-aviation/velis-electro/#tab-id-3.

9 **Shahwan, Kawthar.** Diva-portal. [Online] 2021. https://www.diva-portal.org/smash/get/diva2:1631695/FULLTEXT01.pdf.

10 **Dutch Ministry of Finance.** [Online] https://www.rijksoverheid.nl/onderwerpen/milieubelastingen/vliegbelasting.

11 **Wolters Kluwer.** [Online] 2022. https://www.taxlive.nl/nl/documenten/nieuws/vliegbelasting-waarschijnlijk-naar-24-euro-per-vlucht/#:~:text=De%20vliegbelasting%20wordt%20naar%20verwachting,uit%20het%20herstel%2D%20en%20veerkrachtfonds.

12 **Dutch Ministry of Infrastructure and Water.** Verandwoord vliegen naar 2050. [Online] 2020. https://open.overheid.nl/repository/ronl-c2ae4e29-a960-4c91-99af-7bca52b8c9f9/1/pdf/Luchtvaartnota%202020-2050.pdf.

a **Kyle Field. Clean Technica. Clean Technica.** [Online] 19 February 2020. https://cleantechnica.com/2020/02/19/bloombergnef-lithium-ion-battery-cell-densities-have-almost-tripled-since-2010/.

b **Vehicle Technologies Offics.** Office of Energy Efficiency & Renewable Energy. [Online] 18 April 2022. https://www.energy.gov/eere/vehicles/articles/fotw-1234-april-18-2022-volumetric-energy-density-lithium-ion-batteries.

c **The Economist.** The Economist. The Economist. [Online] 14 August 2017. https://www.economist.com/graphic-detail/2017/08/14/the-growth-of-lithium-ion-battery-power?fsrc=scn%2Ftw%2Fte%2Fbl%2Fed%2F.**<?>**
Halvorson, Bengt. Green Car Reports. [Online] 2019. Electric-car battery prices dropped 13% in 2019, will reach $100/kwh in 2023 (greencarreports.com).

d **Bengt Halvorson.** Electric Cars. https://www.greencarreports.com/news/1126308_electric-car-battery-prices-dropped-13-in-2019-will-reach-100-kwh-in-2023. [Online] December 2019. https://www.greencarreports.com/news/1126308_electric-car-battery-prices-dropped-13-in-2019-will-reach-100-kwh-in-2023.

e **Pippa Stevens.** CNBC. [Online] 30 December 2019. https://www.cnbc.com/2019/12/30/battery-developments-in-the-last-decade-created-a-seismic-shift-that-will-play-out-in-the-next-10-years.html.

NACO

a company of Royal HaskoningDHV

NACO (Netherlands Airport Consultants), part of Royal HaskoningDHV, is a world-leading airport consultancy and engineering firm with over 70 years' experience working in the aviation and air transport industry – from major landmark designs to smaller regional airports.

Since 1949, NACO has provided integrated and multi-disciplinary airport planning and design services for 600 airports in more than 100 countries. We work with our clients to solve the increasing complexities that come with developing world-class, future-proof airports.

Contributing to airport development is at the heart of our mission. From Strategic Development Studies and Airport Master Planning to Passenger Terminal Building Design and Airside Engineering, we provide innovative, sustainable solutions tailored to meet the local requirements for our clients.

Marcel Langeslag

+27 87 352 1500

marcel.langeslag@rhdhv.com

www.naco.nl

in/marcel-langeslag-77bb7510

AVIADEV AFRICA

AviaDev is embedded within and dedicated to the African continent. It is the premier platform dedicated to growing connectivity to, from, and within the African continent.

Bringing together airports, airlines, tourism authorities, governments and industry suppliers, AviaDev offers attendees the ability to pre-arrange meetings, learn from industry peers and make those important connections. AviaDev has established itself as a trusted platform offering insight and bringing together key voices from the African aviation sector.

AviaDev has been delivering digital content to the industry for over 5 years through candid podcasts, video's and social media posts.

Jon Howell

jon.howell@thebench.com

africa.aviationdevelop.com

in/jonh1