AHEV Actieprogramma Hybride Elektrisch Vliegen


# Progress update of the Action Programme Hybrid Electric Flying (AHEV)

*December 1, 2022*

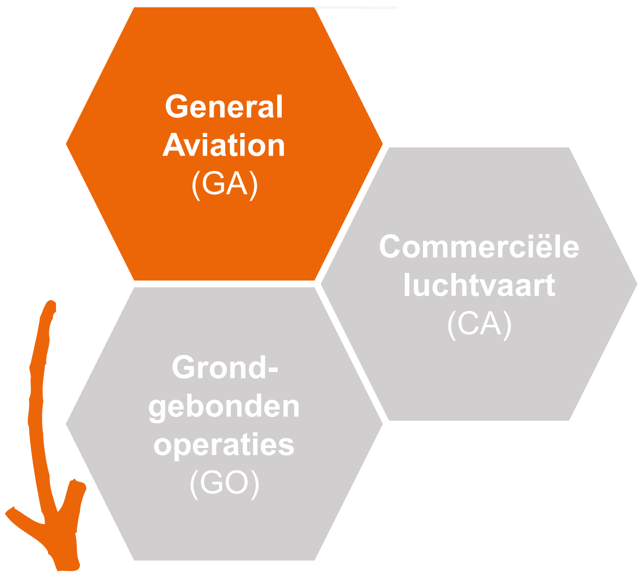
# Management samenvatting (NL) – Introductie

Het Actieprogramma Hybride Elektrisch Vliegen (AHEV) stelt als doel om kennis te delen, (hybride-) elektrisch vliegen strategisch te positioneren en met concrete projecten te stimuleren. AHEV maakt onderdeel uit van het Akkoord Duurzame Luchtvaart. In deze voortgangsrapportage[1] wordt inzicht gegeven in de ontwikkelingen rond het elektrisch vliegen. AHEV bestaat uit drie onderling verbonden roadmaps:

| | Definitie | Ambities 2030[2] (zoals gesteld in 2020) |
|---|---|---|
| **General Aviation** (GA) | Alle niet commerciële luchttransport. GA vertegenwoordigt privé transport en recreatieve luchtvaart | • 'Living lab' voor innovatie in commerciële luchtvaart<br>• 15% afname in uitstoot ten opzichte van 1990 voor binnenlandse General Aviation |
| **Commerciële luchtvaart** (CA) | Alle luchtvaart uitgerust met transponders, met commerciële doeleinden, inclusief internationale privévluchten en zakelijke jets | • Eerste hybride elektrisch vliegtuig met 20 - 50 passagiers in gebruik<br>• Uitstoot van internationale luchtvaart activiteiten in Nederland in 2030 gelijk aan uitstoot in 2005 |
| **Grond-gebonden operaties** (GO) | Activiteiten gerelateerd aan onderhoud, energietoevoer en afhandeling van vliegtuigen, inclusief transport van mensen en goeden en energietoevoer naar gebouwen op luchtvaartterrein | • Uitstoot van grondgebonden operaties afgenomen met 100%<br>• Elektrisch taxiën is standaardprocedure |

Noot: 1) Dit rapport is tot stand gekomen op basis van input aangeleverd door de focusgroeptrekkers; 2) Gebaseerd op de ambities zoals beschreven in Concept Actieprogramma Hybride Elektrisch Vliegen, welke overeenkomen met de huidige ambities

# Management samenvatting (NL) – General Aviation





*Pipistrel Velis Electric: operationele elektrische tweezitter*

**Oorspronkelijke ambitie (zoals gesteld in 2020)**

- ‘Living lab’ voor innovatie in commerciële luchtvaart
- 15% afname in uitstoot ten opzichte van 1990 voor binnelandse General Aviation

**Huidige status t.o.v. ambitie**

Na de introductie van Pipistrel (2-zits) in 2020, vliegen inmiddels meerdere exemplaren in Nederland. Daarmee is opschaling van batterij-elektrisch een mogelijke volgende stap. General Aviation staat zo aan de voorkant van innovatie en kan dienen als vliegwiel en kraamkamer voor innovatie in elektrische luchtvaart o.a. door de ontwikkeling van standaarden en regelgeving. Het is onduidelijk wat de voortgang is ten opzichte van de ambitie om 15% minder uitstoot te realiseren in 2030 t.o.v. 1990, doordat het huidige uitstootniveau en het niveau van het referentiejaar onbekend zijn. Wel is voortuitgang geboekt met de volgende mijlpalen:

- ✓ Demonstratievlucht met Pipistrel op Aruba bij ‘A flight to the future’ conferentie
- ✓ Opzet van Stichting Duurzaam Vliegen als link tussen IenW, AHEV en begunstigden
- ✓ Business cases t.a.v. Regionale Air Mobility (RAM)
- ✓ Nieuwe ronde financiering voor het Dutch Electric Aviation Centre (DEAC)

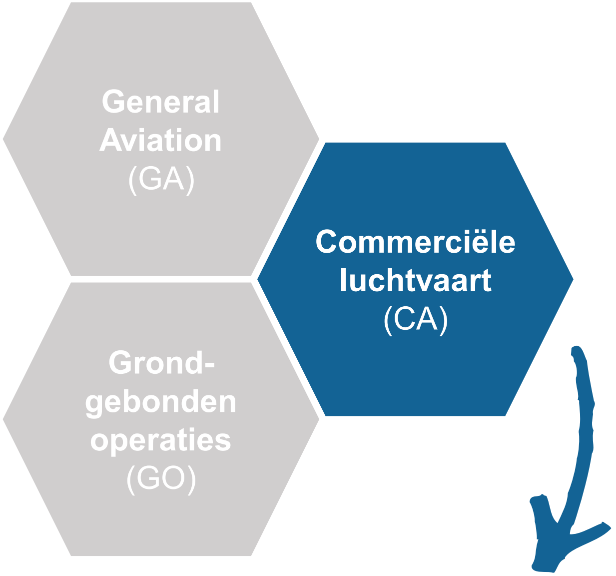
**Uitdagingen**

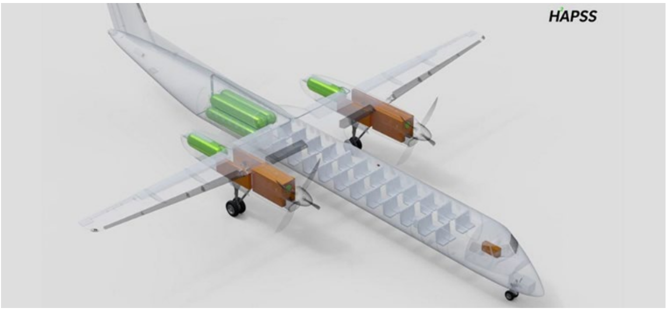
1. Beperkte NL wetgeving beschikbaar voor elektrisch vliegen, voornamelijk gebruikmakend van vrijstellingen
2. Belang GA als vliegwiel voor innovatie vaak onderschat omdat de markt en scope klein is, terwijl het potentieel voor standaardisatie, en voor opschaling naar nieuwe vormen van mobiliteit er is
3. Beperkte standaardisatie en onzekerheid over regelgeving staat investeringen in de weg
4. Aandacht houden voor voldoende opgeleid personeel nodig voor snelle transitie naar elektrisch vliegen

**Mogelijk handelingsperspectief overheid**

1. Geef duidelijkheid over de noodzaak van elektrisch vliegen en maak zo de markt voorspelbaarder, daarmee ontstaan betere business cases en investeringspotentieel
2. Ga door met het ontwikkelen van experimentwetgeving voor elektrisch vliegen (loopt)
3. Draag bij aan standaardisatie van laadinfrastructuur t.b.v. het aantrekken van investeringen
4. Stimuleer elektrisch vliegen als onderdeel van opleiding en training
5. Onderzoek de kwantitatieve voortgang in de reductie van uitstoot en monitor de doelstellingen
6. Behandel General Aviation als onderdeel van de Innovatiestrategie voor de Luchtvaart

# Management samenvatting (NL) – Commerciële luchtvaart




*HAPPS: waterstof aandrijflijn voor retrofit in ontwikkeling*

**Oorspronkelijke ambitie (zoals gesteld in 2020)**

- Eerste hybride elektrisch vliegtuig met 20 - 50 passagiers in gebruik
- Uitstoot van internationale luchtvaart activiteiten in Nederland in 2030 gelijk aan uitstoot in 2005

**Huidige status t.o.v. ambitie**

Voor batterij-elektrisch vliegen is de inschatting dat 19-zitters met <500km reikwijdte technisch haalbaar zijn rond 2030. Ook in Nederland wordt veel onderzoek gedaan. Waterstof-elektrisch (fuel cell) aangedreven vliegtuigen met 40-80-stoelen en ~2000km reikwijdte zijn mogelijk technisch haalbaar in 2040. Elektrisch vliegen (batterij of waterstof brandstofcel) zal pas grootschalig door de markt worden geadopteerd bij lagere kosten t.o.v. fossiel. Als deze kosten niet lager zijn is overheidsingrijpen noodzakelijk voor volledige transitie. Behaalde mijlpalen zijn o.a.:

- ✓ De ontwikkeling van Hydrogen Aircraft Powertrain en Storage Systems (HAPSS)
- ✓ De (gedeeltelijke) toekenning van €383 miljoen voor Luchtvaart in Transitie uit het Nationaal Groeifonds aan AHEV partners
- ✓ Oplevering Masterplan Elektrisch Vliegen en Roadmap Elektrisch Vliegen

**Uitdagingen**

1. Tijdige beschikbaarheid van relevante technologie
2. Benodigde investeringen in laadinfrastructuur en/of waterstofinfrastructuur
3. Onzekerheid in de ontwikkeling en vorm van toekomstige markten
4. Mogelijke incoherentie tussen (inter-)nationale wetgeving en doelen wat leidt tot verstoring van het level-playing field

**Mogelijk handelingsperspectief overheid**

1. Laat doelen en beleid van de overheid meebewegen met de beschikbare technologie, bijvoorbeeld:
   a. Horizon 2030: elektrisch vliegen stimuleren in Caribisch gebied en verplichten, mits de technologie zich voldoende heeft ontwikkeld
   b. Horizon 2040: Stimuleer verdere ontwikkeling van waterstof brandstofcel in luchtvaart
   c. Horizon 2050: (Gefaseerd) verplicht zero emissie vliegen, bijvoorbeeld zakelijke als eerst. Mits technologie zich ontwikkelt zoals verwacht
2. Vertaal bovenstaande horizonnen naar concrete roadmaps als invulling van de innovatiestrategie voor de luchtvaart

# Management samenvatting (NL) – Grondgebonden operaties

General Aviation (GA)

Commerciële luchtvaart (CA)

**Grond-gebonden operaties (GO)**


*eGPU verzorgt stroom voor stationair vliegtuig zonder emissie*

**Oorspronkelijke ambitie (zoals gesteld in 2020)**

- Uitstoot van grondgebonden operaties afgenomen met 100%
- Elektrisch taxiën is standaardprocedure

**Huidige status t.o.v. ambitie**

Een grote variëteit aan materieel is nodig om luchtoperaties op de grond te ondersteunen. Enkele types materieel zijn door de lage aantallen en unieke specificaties lastiger te verduurzamen. Het lichte materieel (bijv. vliegtuigtrappen) en energietoevoer voor stilstaande vliegtuigen zijn naar verwachting emissie-vrij in 2030. Het zwaardere materieel (bijv. brandweer of sneeuwvloot) zal later pas vervangen worden; dit heeft beperkte en compenseerbare impact. Er wordt momenteel overgegaan van fossiel naar groen gas en groene stroom (RSG werkt al op groene stroom) voor de gebouwen op luchthavens. Uitdagingen blijven bestaan op het gebied van duurzaam taxiën. Behaalde mijlpalen zijn o.a.:

- ✓ Start vervanging diesel GPU’s door eGPU’s
- ✓ Implementatie van zonneparken bij vliegvelden (Bijv. Schiphol, Rotterdam-Den-Haag, Eelde)
- ✓ Pilot uitgevoerd Hydrotreated Vegetable Oil (HVO100) brandstof, invoering wordt nu gestart

**Uitdagingen**

1. Grote investeringen zijn nodig om het zware materieel voor het einde van de levenscyclus te vervangen, transitie is mogelijk, bijvoorbeeld d.m.v. fossielvrije brandstof (bv HVO100)
2. Complexe coördinatie in de gedeelde verantwoordelijkheid van luchthavens, airlines en afhandelaren. Gecoördineerd handelen is nodig met het hele ecosysteem (incl. leveranciers van materieel)
3. Opschalen duurzaam taxiën is complex

**Mogelijk handelingsperspectief overheid**

1. Stimuleer de versnelde vervanging van materieel en ondersteun de beschikbaarheid van voldoende laadcapaciteit en bijbehorende duurzame energie en infrastructuur
2. Ondersteun werkgroep Duurzaam Taxiën
3. Behandel grondgebonden operaties als onderdeel van de Innovatiestrategie voor de Luchtvaart
4. Monitor de ontwikkeling van grondgebonden uitstoot op luchthavens

# Executive summary (ENG) – Introduction

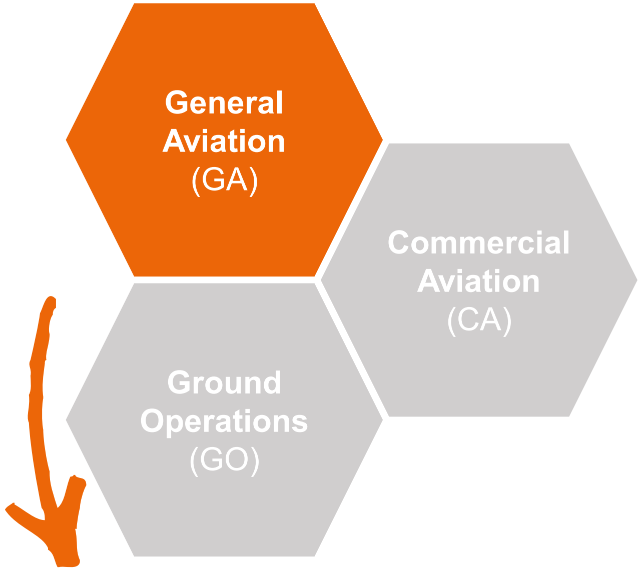
AHEV aims to build connections, share knowledge and information, aid in strategic positioning of electric flight and execute related projects. This document[1] provides insights into the developments regarding electric flying. Three AHEV roadmaps have distinct scopes but interlinked scopes

| | Definition | **Ambitions 2030[2]** (as stated in 2020) |
|---|---|---|
| **General Aviation** (GA) | All non-commercial aviation. GA represents private transport and recreational aviation | • 'Living lab' for innovations in commercial aviation<br>• 15% reduction of domestic General Aviation emission levels compared to 1990 |
| **Commercial Aviation** (CA) | All aviation equipped with transponders, with commercial intent, including international private flights and business jets | • First hybrid electric aircraft with 20-50 passengers in use<br>• International aviation activities in the Netherlands in 2030 to emission levels of 2005 |
| **Ground Operations** (GO) | Activities related to maintenance, energy supply and aircraft handling, including transport of people or goods and energy supply to related buildings on airside | • Emissions ground operations reduced with 100%<br>• Electric taxiing is standard procedure |



Note: 1) This document is based on the input provided by the focus group leads; 2) Based on the ambitions as described in Concept Actieprogramma Hybride Elektrisch Vliegen, which continue to be the ambitions today

# Executive summary (ENG) – General Aviation




*Pipistrel Velis Electric: operational electric 2-seater*

## Original ambition (as stated in 2020)

- ‘Living lab’ for innovations in commercial aviation
- 15% reduction of domestic General Aviation emission levels compared to 1990

## Current status versus ambition

After the introduction of Pipistrel (2-seater) in 2020, currently multiple are in use in the Netherlands. With that, battery-electric aviation at scale is a potential next step. This way, General Aviation is a front-runner in innovation and can serve as a flywheel and incubator for innovation in electric aviation, e.g. in the development of standards and policy. Currently, it is unknown to what extend the ambition is realized to reduce emission by 15% in 2030 versus 1990, as both the current emission level and the emission level in the reference year are unknown. Examples of achieved milestones are:

- ✓ Demonstrator flight with Pipistrel on Aruba during the ‘A flight to the future’ conference
- ✓ Launch of ‘Stichting Duurzaam Vliegen’ as linking pin between IenW, AHEV and stakeholders
- ✓ Business cases in relation to Regional Air Mobility (RAM)
- ✓ New round of financing for the Dutch Electric Aviation Centre (DEAC)

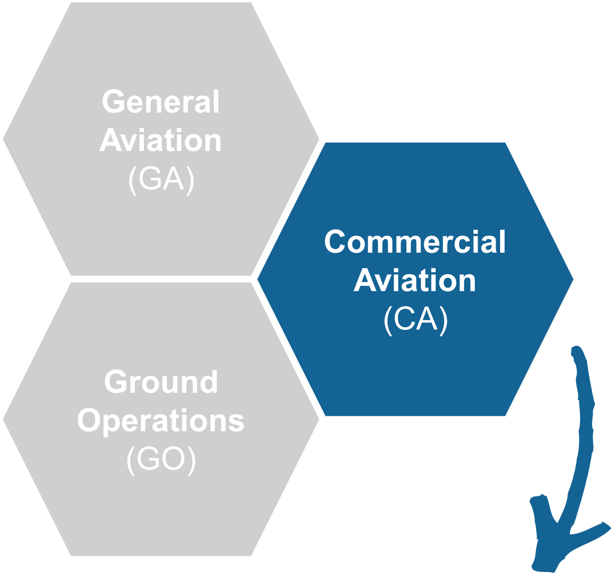
## Challenges

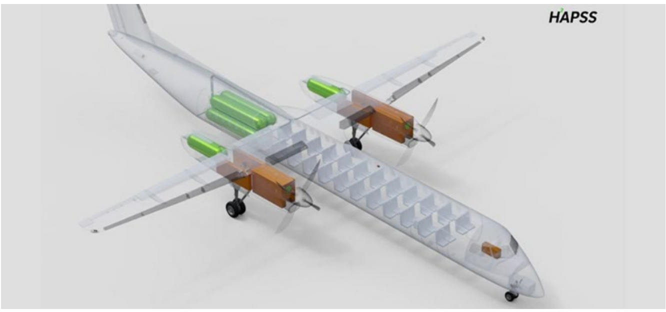
1. Limited NL policy and regulations for electric aviation, currently mainly through waivers
2. Importance of GA as flywheel for innovation is underestimated because market and scope are small, while the potential for standardization and for scaling up to new forms mobility exists
3. Limited standardization and uncertainty around regulations is a barrier to investment
4. Be aware of sufficiently trained staff needed for a fast transition to electric aviation

## Potential perspectives for government action

1. Provide clarity on the necessity of electric aviation and make the market more predictable, such that business cases and investment potential increase
2. Continue the development of policy that allows for experiments in electric aviation (on-going)
3. Support the standardization of charging infrastructure in order to stimulate investments
4. Incentivize electric aviation as part of training and education
5. Research the quantitative progress towards the reduction of emission and monitor goals
6. Include General Aviation as part of the Aviation Innovation Strategy

# Executive summary (ENG) – Commercial Aviation




*HAPPS: hydrogen powertrain for retrofit currently developed*

**Original ambition (as stated in 2020)**

- First hybrid electric aircraft with 20-50 passengers in use
- International aviation activities in the Netherlands in 2030 to emission levels of 2005

**Current status versus ambition**

For battery-electric aviation 19-seaters with <500 km range are expected to be feasible in 2030. Hydrogen-electric (fuel-cell) powered aircraft with 40-80 seats and approximately 2000 km range are expected to be possibly technically feasible in 2040. Electric aviation (battery of hydrogen fuel-cell) will only be adopted by the market when cost are lower versus fossil fuel. If costs are not lower, then government intervention is necessary to drive adoption. Examples of achieved milestones are:

- ✓ Initiated the development of Hydrogen Aircraft Powertrain and Storage Systems (HAPSS)
- ✓ A (partial) grant of €383 million for Aviation in Transition ('Luchtvaart in Transitie') from the 'Nationaal Groeifonds' to AHEV partners
- ✓ Completion of Masterplan Electric Aviation and Roadmap Electric Aviation

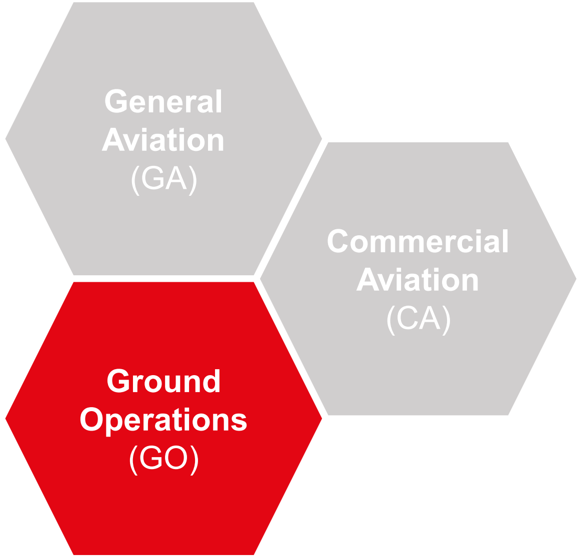
**Challenges**

1. Timely availability of electric aircraft technology
2. Investments in (charging) infrastructure and/or hydrogen infrastructure
3. Uncertainty in development and shape of future markets
4. Potential incoherence between (inter-)national legislation and goals leading to a disruption of the level-playing field

**Potential perspectives for government action**

1. Ensure goals are set and policy is developed in line with the availability of the technology over time e.g.:
    a. Horizon 2030: Mandatory electric aviation in Dutch Caribbean if the technology continues to develop as expected
    b. Horizon 2040: Stimulate hydrogen fuel cell in aviation
    c. Horizon 2050: (Phased) Mandatory zero emission aviation if the technology continues to develop as expected
2. Translate these horizons into roadmaps as translation of the Aviation Innovation Strategy

# Executive summary (ENG) – Ground Operations





*eGPU supplies power to stationary aircraft without emissions*

**Original ambition (as stated in 2020)**

- Emissions ground operations reduced with 100%
- Electric taxiing is standard procedure

**Current status versus ambition**

A wide range of equipment is used to support flying operations: light (e.g. plane stairs) and stationary aircraft power supply are likely to be replaced by emission-free equipment in 2030. Heavy equipment (e.g. firefighting trucks) will be replaced later but has limited total emissions. Energy supply for buildings is transitioning from fossil gas to green gas and electricity (RSG uses 100% renewable electricity). Challenges remain around electric taxiing. Examples of achieved milestones are:

- ✓ Start replacement of diesel GPU's with eGPU's
- ✓ Implementation of solar parks at airports (e.g. Schiphol, Rotterdam-the Hague, Eelde)
- ✓ Pilot succesfully executed with Hydrotreated Vegetable Oil (HVO100), implementation started

**Challenges**

1. Significant investments necessary to replace large equipment before end of lifecycle, transition is possible using HVO100 fuels
2. Complex coordination given shared responsibility airports, airlines and handlers. Concerted efforts throughout the ecosystem (incl. GSE suppliers) is needed to resolve issues
3. Sustainable taxiing is difficult to implement and has limited scope for benefit realization

**Potential perspectives for government action**

1. Stimulate fleet replacement of aircraft handling equipment and support the availability of sufficient charging capacity, including sustainable energy supply and necessary infrastructure
2. Support the working group sustainable taxiing
3. Include Ground Operations development in the Aviation Innovation strategy
4. Monitor the reduction of emissions from Ground Operations

# Introduction:
# This progress update provides insight in the viability of the goals set in AHEV

For each of the three roadmaps this update describes the milestones delivered, the viability of the end goals and the potential actions for government to support the realization of the end goals

| AHEV goals[1] | 2030 | 2050 | 2070 |
|---|---|---|---|
| **General Aviation** | Living lab for innovation of commercial aviation. 15% reduction of GA emissions in 2030, compared to 1990 | Zero emission in domestic aviation in 2050 | |
| **Commercial Aviation** | First hybrid-electric aircraft with 20-30 pax in use. Int'l commercial aviation activities from the Netherlands at 2005-level | Underwrite ICAO goalsetting. All short-distance flights from the Netherlands <500 km fully electric | Zero emission international aviation as dot on the horizon |
| **Ground Operations** | Emissions of ground operations reduced by 100%. Electric taxiing is standard procedure | | |

## In scope

- **Commercial aviation 2050: all short distance-flights (<500km) fully electric** – a new quantitative quick scan is carried out as part of this update. For this report only fully electric aircraft are in scope, i.e. hydrogen fuel-cell electric or battery electric. Hybrid aircraft with combustion engine (either aviation fuel or hydrogen) are out of scope
- **2030 emissions of ground operations reduced by 100%** – reporting is quantified as part of this update; it is expected that in 2023 TNO will provide a more detailed analysis of ground operations
- **Qualitative maturity on General Aviation** – an analysis on the perceived maturity of GA towards the goals in 2030 and 2050

## Out of scope

- Other goals may be put in perspective by the sector or are out of scope for AHEV because of its focus on (hybrid-) electric
- **Zero emission domestic aviation 2050** (defined as non-IFR) – complex analysis with limited expected impact on transition and absolute emissions, **hence out of scope** for this AHEV progress update
- **Commercial aviation 2050: ICAO goals[2]** (net-zero 2050 globally) – achieving this goal is expected to be mainly realized through SAF/Hydrogen, hence **out of scope** for this AHEV progress update
- **2070: Zero emission of international** aviation as dot on the horizon – achieving this goal is expected to be mainly realized through SAF/Hydrogen, hence **out of scope** for this AHEV progress update



Source: 1) Concept Actieprogramma Hybride Elektrisch Vliegen, page 7; 2) Note: ICAO goals dependent on potential new goal setting

# 1. General Aviation

# Electric aviation in General Aviation has been actively promoted and developed

Progress along the three functions of the action program

### I. Build connections, share knowledge and information

- ✓ **Linking and supporting relevant initiatives (coordination/networking)**
- ✓ Set up Stichting Duurzaam Vliegen (SDV) as a linking pin between IenW, AHEV and beneficiaries
- ✓ A sector-led focus group on general aviation has been set up as a result of AHEV

- ✓ **Dissemination of knowledge in curricula of aeronautical courses**
- ✓ Set up link of different types of education at Teuge airport through Dutch Electric Aviation Centre (DEAC)
- ✓ Knowledge institutes started (hydrogen-)electric aviation spin-offs (e.g., AeroDelft)

- ✓ **Publicize developments (creating interest, awareness and support)**
- ✓ Set up platform through SDV
- ✓ Opening and publicizing E-flight Academy

### II. Strategic positioning of hybrid electric technology and innovation

- ✓ **Development of business models**
- ✓ E-Flight Academy has launched for training pilots for electric aviation
- ✓ Start of realistic business cases in Electric Flight Collective (EVC)
- ✓ Business cases around Regional Air Mobility (RAM)

- ✓ **Setting up 'living labs' and (encouraging) knowledge development**
- ✓ First electric flight with the Pipistrel on Aruba during the 'A flight to the future' conference on sustainable aviation
- ✓ Setting up test-bed at Teuge airport (DEAC)

- ✓ **Identification of barriers and preconditions**
- ✓ ADSE whitepaper on certification and experimentation
- ✓ Explored the potential of retrofitting existing propellor aircraft

### III. Execution of programs and projects

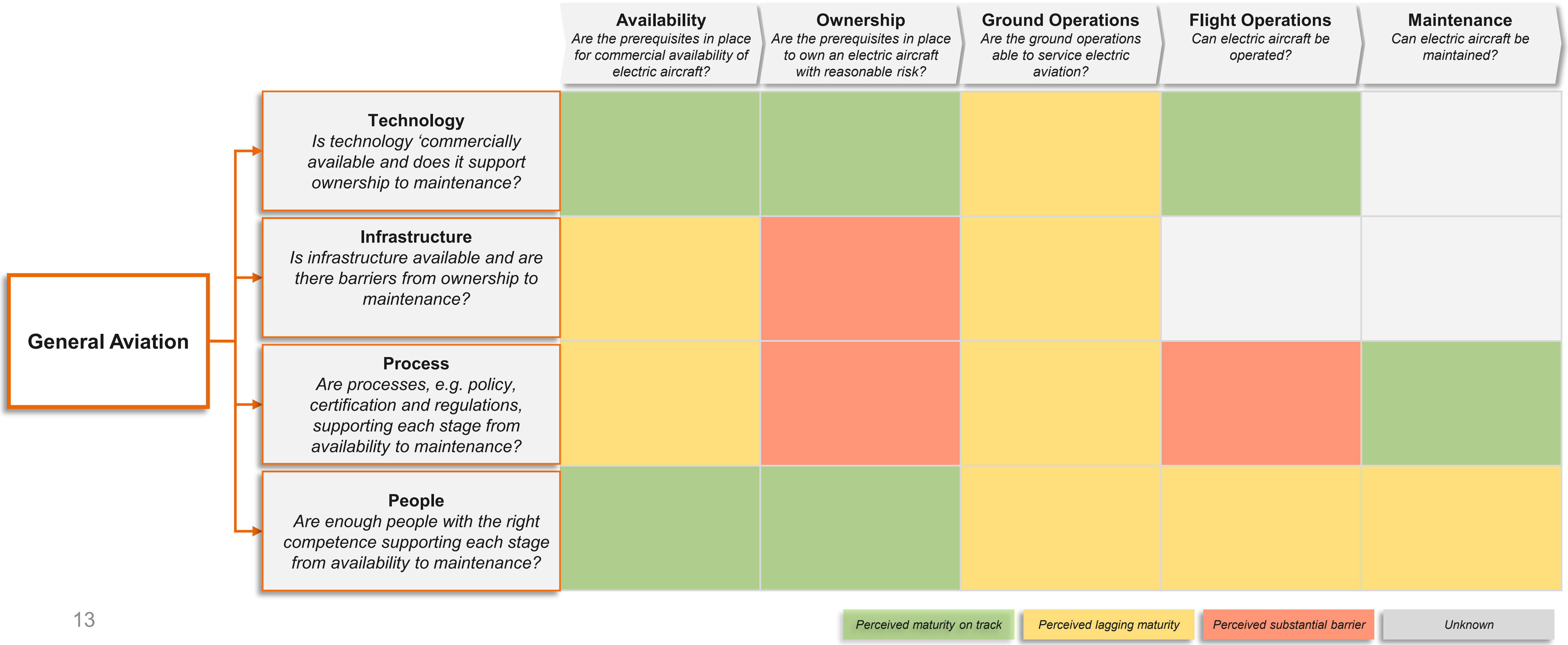
- ✓ **Mapping 'requirements' of the GA sector (supply and demand respectively)**
- ✓ More commercial activity around GA is creating more demand for requirement mapping

- ✓ **Mapping possibilities for funding and subsidies (creating capacity)**
- ✓ Working on shared story of GA as innovation flywheel for commercial aviation to external stakeholders

- ✓ **Mapping (inter)national initiatives and developments**
- ✓ Developed Masterplan Electric Flight at the Dutch Caribbean

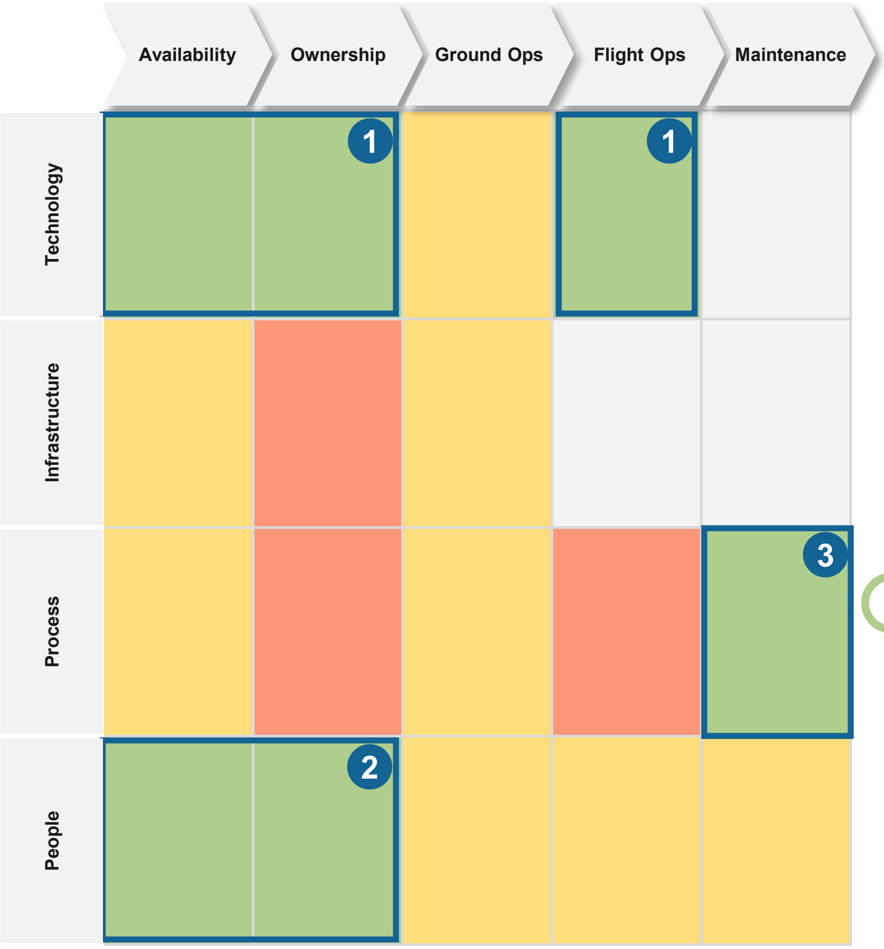
# Process and infrastructure are perceived as main barriers in General Aviation (GA)

Perceived barriers in GA along the lifecycle (stages availability – maintenance) are plotted for each of the four segments (technology – people) necessary to transform GA towards the 2030 goals



# Technology and People within GA is generally on the right developmental track

Areas that need accelerated development and areas with substantial barriers are discussed on slide 15 and 16, respectively.




## 1 Technology in GA

- Technology development necessary for GA to achieve the 2030 goals are assumed to be on-track[1]. Tour of the Netherlands *('Rondje Nederland')* raised awareness of the new possibilities of electric flight throughout the Netherlands
- It is possible to own an electric aircraft in the Netherlands with the introduction of the Pipistrel Velis Electro which is commercially available. In addition, knowledge institutes are starting spin-offs (e.g. Aerodelft).
- Masterplan Electric Flight as a test case for electric flying in the Dutch Caribbean

! More alternatives in technology (incl. retrofit) are expected and are needed to enable a 'healthy' market

## 2 People in GA

- Setting up Stichting Duurzaam Vliegen (SDV) as a linking pin between IenW, AHEV and beneficiaries, functioning as a platform to share developments and knowledge
- DEAC has finished developing their own Flying Testbed to prepare education for electric flight in the Netherlands
- Finished setting up the Living Lab by NLR, a research platform for knowledge exchange

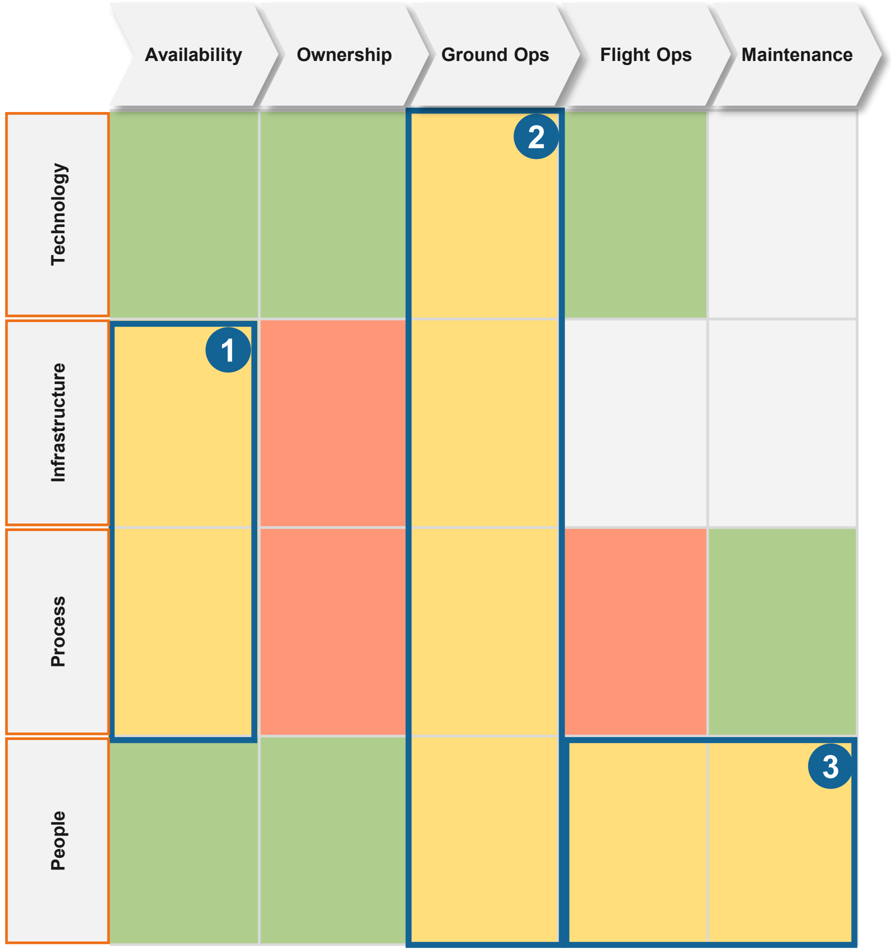
## 3 Processes in GA

- ADSE paper published on the topic of (regulatory) space to experiment and the possibilities of testing electric flight in the Netherlands, to emphasize the next steps necessary
- Typically, maintenance of electric aircraft is not substantially different from non-electric aircraft

Note: 1) Based on expert opinion. Quantitative insights into the current emission levels and the emission level of the reference year (1990) are currently not available.

*Perceived maturity on track* | *Perceived lagging maturity* | *Perceived substantial barrier* | *Unknown*

# Development of infrastructure, ground ops and education can boost electric GA




## 1 Availability of infra. and process

- Limited availability of charging infrastructure due to lack of standardization and scale
- Policy development on testing and experimenting must continue, as now mainly waivers from existing legislation are available
- Currently it is expensive to test and experiment, hindering innovation (e.g. due to insurance)
- Need for better understanding of impact on lower airspace capacity with increasing ATMs

## 2 Ground ops. in GA

- Need for better regulatory framework, vision and guidance from the government
- Not all ground operations are compatible with electric flying, e.g. emergency response to lithium-ion battery or hydrogen calamities

## 3 People in flight ops. and maintenance

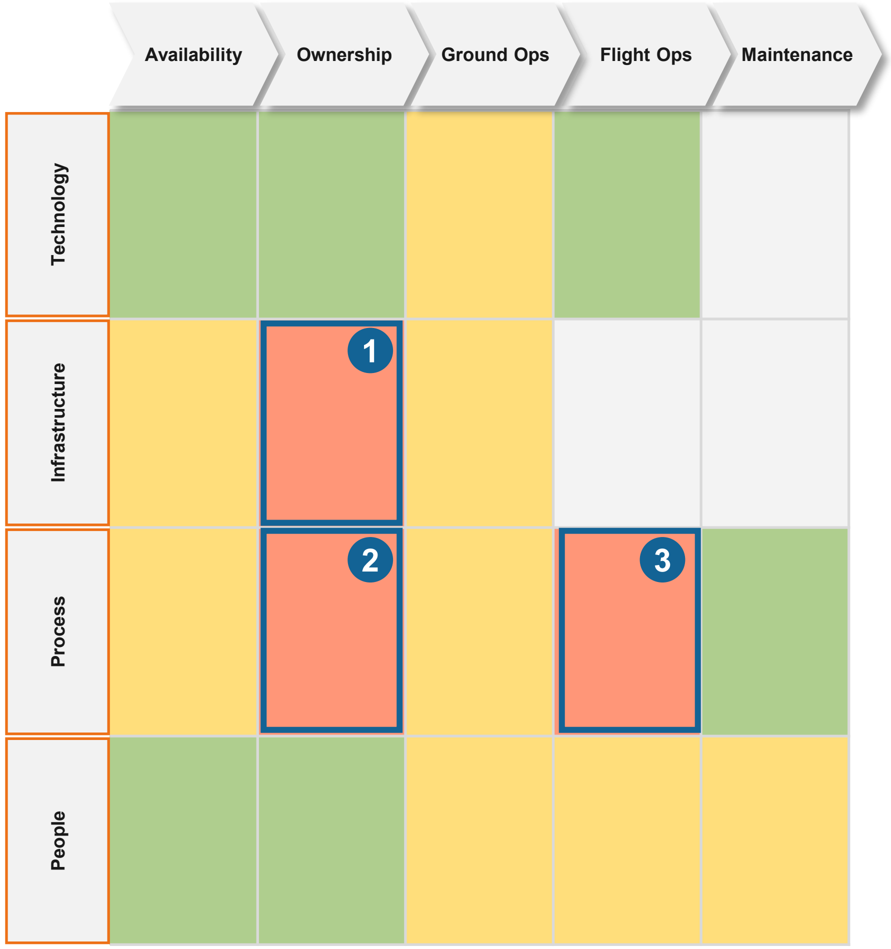
- Currently pilots are trained non-electric by default. Making electric flying in the curriculum the standard would lower barriers for pilots and reduce emissions of flight schools

## Potential for government actions

- **Further develop regulatory framework**
  Better regulatory support could help the continued development of electric aviation. Current structure with waivers from existing legislation is not ideal for innovation. Predictability of legislation is important for entrepreneurs in order to give clarity on their business case and investments
- **Adequate capacity of electricity grids**
  To enable electric aviation at scale, adequate capacity of electricity grids is required. This will require coordination across stakeholders, e.g., network operators, airports, etc.
- **Include electric flying in education**
  Stimulate electric aviation in aviation-related studies and at flight schools

*Perceived maturity on track* | *Perceived lagging maturity* | *Perceived substantial barrier* | *Unknown*

# Substantial barriers are identified in ownership of infrastructure and processes




## 1 Ownership of infrastructure

- There is specific need for standardization and resulting predictability of the development of business cases. These business cases are needed to stimulate owning charging infrastructure

## 2 Process of ownership

- Currently, mainly waivers are given regarding legislation around operating electric aircraft. This results in a significant barrier regarding insurance. Insurance for electric aircraft is currently expensive because insurers cannot properly assess risks for electric aviation yet

## 3 Processes in flight operations

- Operating electric aircraft requires a specific electric flying pilot's license. The license is obtained through a waiver from legislation, though only one flight school in the Netherlands is equipped to issue these

## Potential for government actions

- **Support standardization for charging infra**
  GA investors value standardization and predictability in their business cases regarding charging infrastructure for aviation. That would mean more interesting business cases, and therefore making ownership more attractive
- **De-risk insurance in electric aviation and implement suitable policy**
  Currently, insurance for electric flight is expensive compared to traditional flight, which is a barrier for adoption of electric aviation. With the right policy framework, it is easier for insurance companies to assess risks, such that electric aviation and non-electric aviation can be insured at equivalent price proportional to the risk
- **Connect with European legislation**
  Conversations within and in Europe can help to create a coherent vision and government guidance creating a clearer and more certain future market. To exemplify, clear legislation on GA could strengthen GA as a flywheel for CA

*Perceived maturity on track* | *Perceived lagging maturity* | *Perceived substantial barrier* | *Unknown*

# 2. Commercial Aviation

# Commercial Aviation starts to develop prototypes of future zero emission aircraft

Progress of along the three functions of the action program

### I. Build connections, share knowledge and information

- ✓ **Ecosystem focal point**
- ✓ A sector-led focus group on commercial aviation has been set up as a result of AHEV
- ✓ The original concept of AHEV has been used as a starting point for discussion around battery- and hydrogen-electric flight

- ✓ **Global Aviation Innovation Analysis**
- ✓ Defines the scope, importance and goals for innovation and analyzes various relevant topics for the Netherlands in an international context

- ✓ **Power Up**
- ✓ Dutch airports supported by NLR are going to carry out tests with electric flying to gain knowledge of the feasibility of electric flights

### II. Strategic positioning of hybrid electric technology and innovation

- ✓ **Nationaal Groeifonds**
- ✓ A consortium of partners from AHEV have been granted €383 million (of which €119 million conditional) for the program 'Aviation in Transition' to drive the development of sustainable aviation. For this grant the concept of AHEV was used as an important input document

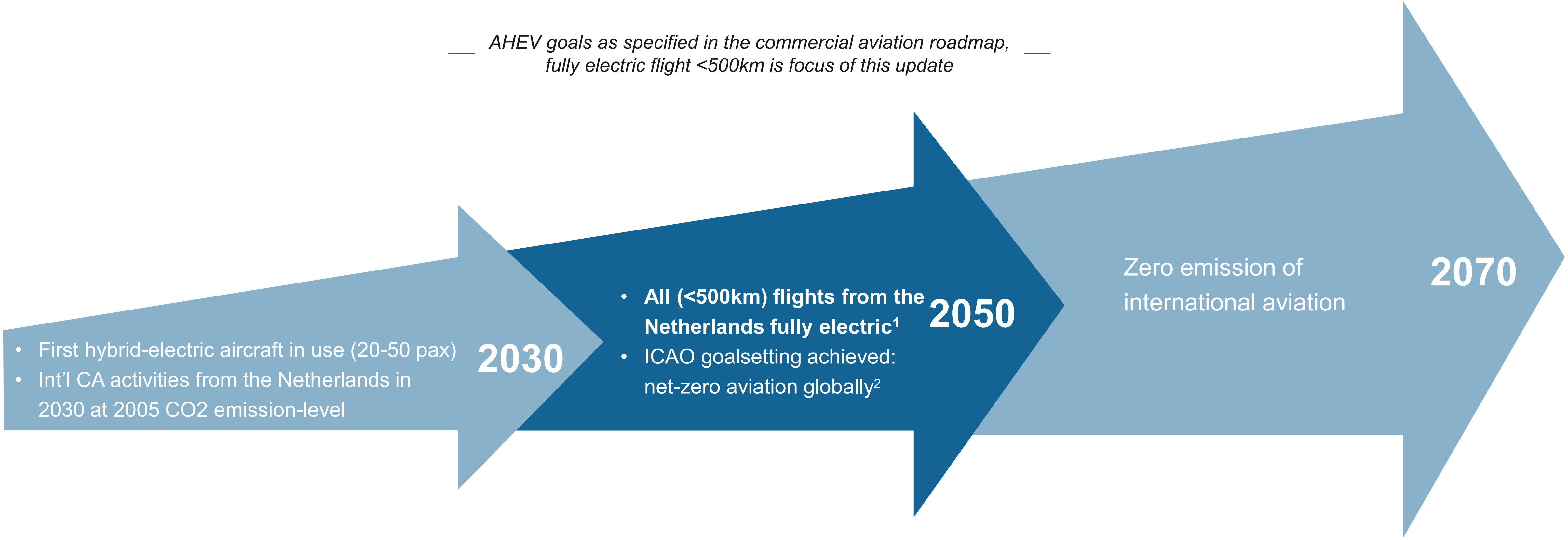
- ✓ **Aviation innovation strategy**
- ✓ Analyzes the innovation capacity and main barriers facing the Dutch ecosystem to increase the innovation capacity
- ✓ Proposes measures to overcome the barriers and a monitor to assess the impact of the proposed measures

### III. Execution of programs and projects

- ✓ **HAPSS**
- ✓ Initiated the development of Hydrogen Aircraft Powertrain and Storage Systems (HAPSS)
- ✓ Aims to be available to retrofit aircraft starting in 2025
- ✓ Based on Hydrogen fuel cell and electric turboprop engines

# AHEV set the ambition for all commercial flights <500km from the Netherlands to be fully electric by 2050

*AHEV goals as specified in the commercial aviation roadmap, fully electric flight <500km is focus of this update*




 Note: 1) Hydrogen-electric is also in scope of AHEV; 2) https://www.icao.int/Newsroom/Pages/States-adopts-netzero-2050-aspirational-goal-for-international-flight-operations.aspx

# Electric aviation is expected to take off in the coming years; with availability of 9- and 19-pax battery-electric by 2030 and 40- and 80-pax hydrogen-electric by 2040

Currently various initiatives are at an early stage (especially the larger aircraft); smaller aircraft aim to use battery-electric propulsion, while larger aircraft tend to use hydrogen-electric propulsion (see appendix for context)

**Timeline of announced electric aircraft[1]**

Battery-electric aircraft | Hydrogen-electric aircraft

**New built aircraft / retrofits**

**Pipistrel VelixE**
2 pax / 140 km
EIS actual: 2020

**Bye eFlyer2**
2 pax / 400 km
EIS target: 2023

**Eviation Alice**
9 pax / 815 km
EIS target: 2025

**Tecnam PVolt**
9 pax / 157 km
EIS target: 2026

**Zero Avia**
40 pax / 1800 km
EIS target: 2026

**Embraer E9-HE**
9 pax / 925 km
EIS target: 2030

**Maeve 01**
40 pax / 550 km
EIS target: 2030

**(Scalable) powertrains**

**Hydrogen**
40-60 pax /
750 km
EIS target: 2025

**GKN H2GEAR**
40 pax / 750 km
EIS target: 2026

**HAPSS**
40-80 pax /
750 km
EIS target: 2028

2020 → 2030

**Considerations of the roadmap**

- Aircraft have specific sizes due to regulations: 9-pax is the limit for one pilot, 19-pax needs one pilot and one cabin crew
- Due to physical limits, there are increasingly diminishing returns for aircraft size, that are worse for battery-electric than for hydrogen-electric. Fully battery-electric is therefore expected to be only feasible for 9- or 19-pax aircraft, while hydrogen-electric could be used for larger aircraft. Breakthrough battery innovations could change this outlook and make an aircraft like Maeve 01 (40-pax) technically and commercially feasible (see appendix)
- Hybrid battery electric / SAF configurations, e.g. with electric propulsion as take-off assist, are feasible to reduce fuel burn for larger propeller aircraft. However, as they cannot result in zero emission aviation and therefore are out of scope for this quick scan

**Expert's conclusions[2,3]**

- In 2030 commercial up-to 19-pax battery-electric aircraft are feasible
- In 2035 newbuilt commercial 40-pax hydrogen electric aircraft are feasible. Retrofits could be available from 2028-2030, provided these are commercially viable against not retrofitted fossil fuel counterparts
- Potentially 80-pax hydrogen electric aircraft are feasible by early 2040's
- Smaller aircraft (<19-pax) may be suitable for flights between ABC or between SSS as currently used aircraft are also smaller
- Larger aircraft (40- or 80-pax) may be suitable for NL flights < 500 km
- In NL economies of scale are assumed to be positive up to a capacity of 118 passenger seats (current average). For the 40-80 pax range, this means an airline will prefer larger aircraft to realize lower cost/passenger-km

Source: 1) Market scan performed up to 30/11/2022; Unified International; 2) Expert interviews with TO70, Unified International; 3) Monitor Deloitte analysis; Note: 4) Entry into Service as indicated by producer

# Transition to electric flight ideally starts at the OD-pairs with no feasible alternative mode of transport and with high volumes to leverage economies of scale

**Drivers for viability of electric aviation**

- Electrification of aviation should start where (1) feasible alternatives to flying do not exist, and (2) the volume of/ demand for flying is high

  1) The table on the right shows the selected 9 OD pairs within a range of <500 km that have an additional train travel time above 120 minutes, and therefore have no (feasible) alternative to flying

  2) these OD pairs have a significant passenger volume. Volume is important to leverage economies of scale to cover the investments associated with electric aviation (aircraft and infrastructure)

| #c | Origin Airport (ordered by capacity flown) | Destination Airport | 2019 daily flights[2] |
|---|---|---|---|
| 1. | Amsterdam Schiphol | Manchester | 23 |
| 2. | Amsterdam Schiphol | Birmingham | 18 |
| 3. | Amsterdam Schiphol | Hamburg | 12 |
| 4. | Amsterdam Schiphol | Billund | 10 |
| 5. | Amsterdam Schiphol | Leeds Bradford | 8 |
| 6. | Eindhoven | London Stansted | 5 |
| 7. | Amsterdam Schiphol | Luxembourg-Findel | 8 |
| 8. | Amsterdam Schiphol | Norwich | 7 |
| 9. | Amsterdam Schiphol | Southampton | 8 |

**Conclusions** *(further explanation and analysis can be found in the Quick Scan – separate document)*

- Various flights between **large UK cities** and **NL** have **no feasible alternative mode of transport** while they **represent large volumes** of passengers (e.g. Schiphol – Manchester or Schiphol – Birmingham), these OD pairs should be the first to pilot hydrogen electric flying with
- Also, flights between **Schiphol and Hamburg, Billund and Luxembourg** account for a **significant volume** while they **do not have a viable alternative mode** of transport

# Various prerequisites and perspectives for action still need to be realized towards 2050 to enable electric flight < 500 km at scale in The Netherlands

## Challenges

### Timely availability of aircraft

Fleet replacement seems possible in the ten years between expected availability in 2040 and goal in 2050, however later availability of sufficient aircraft, will require a faster transition which is more costly and complex.

### Investments in charging infra

The introduction of zero-emission aircraft requires substantial changes at airports (infrastructure, safety guidelines, training of ground personnel, etc.), both at origin and destination. This means that an approach per OD-pair is recommended

### Uncertainty about future markets

There is currently no certain future market (both demand and supply) that enables manufacturers and investors to fully commit to zero-emission aviation <500 km towards 2050

### Tension with international goals and legislation

Commercial aviation is truly international/global, which means that the influence of individual countries is limited

National goals and legislation should consider ensuring an acceptable level-playing field

## Looking ahead

### Potential perspectives for government action

- Based on expert insights, battery-electric aircraft will be exclusively viable for shorter distances and low capacity. Hydrogen-electric aircraft could be viable for a wider set of OD pairs, provided there are enough passengers per flight to enable economies of scale
- In order to realize battery- or hydrogen-electric aircraft, the government needs to ensure to align goals and policy with the availability of technology. In case the technology needed to achieve a goal is not available yet, stimulation might be needed to accelerate the availability of technology. As soon as the technology is available, a fixed road map to zero emission goals incentivizes market players to invest in the technology. To exemplify, the following policy could be enforced if the technology continues to develop as expected[1]:
  a. Horizon 2040: Stimulate hydrogen fuel cell technological development
  b. Horizon 2050: (Phased) Mandatory zero emission aviation, provided technology develops as expected
- The stimulus of zero-emission aircraft is most effective when delivered across the value chain of supplier, production, airports, airlines and passengers



Note: 1) National policy should be in line with EU policy

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# For the Caribbean challenges are addressed by actions in MoU Sustainable Aviation

Several potential actions are identified including some barriers to implementation of electric flight in the Dutch Caribbean

## Challenges Commercial Aviation specific to Caribbean

### Timely availability of aircraft

1. A prototype 9-seater aircraft (Alice) is currently available, however with current battery technology it is not yet possible to operationalize the aircraft
2. Apart from Alice, various other companies are at an early stage in developing electric aircraft

### Investments in infrastructure

1. Efficient swap or charge system needs to be in place for a healthy business case
2. The current energy mix at the islands is not sustainable, but there is opportunity for wind- and solar-power for a (more) sustainable energy mix.

### Uncertainty about future markets

1. It is easier to give clarity on future markets given the limited scale and complexity of current markets on the Dutch Caribbean

### Tension with international goals and legislation

1. Regulatory pressure and tension is more easily resolved in the Caribbean, rather than the inherently international context of aviation for the NL mainland

## Looking ahead

### Potential perspectives for government action

- A roadmap to electric flight can be driven by the government by supporting development, investing in energy infrastructure and sustainable energy sources
- After the technology becomes available, exclusive electric flight can be part of a future Public Service Obligation (PSO) for flights between the islands

### Memorandum of Understanding on Sustainable Aviation on the islands

An MoU between Dutch government, governments of the islands, local airports and the Dutch airport association (NVL) defines the following action: Form a task force for the purpose of developing a joint strategic plan and interisland innovation center for sustainable aviation. This includes:

1. Steps needed to act on developed strategy, with identified financing details and barriers
2. Establishment of interisland innovation center for sustainable aviation
3. Possibilities, means and measures to achieve a smooth, seamless and efficient flow of passengers
4. Recommendations on necessary change of laws, regulations and policy pertaining to the end goal

# 3. Ground Operations

AHEV Actieprogramma Hybride Elektrisch Vliegen

# High-level progress update on Ground Operations: finished actions or projects

Progress along the three functions of the action program

### I. Build connections, share knowledge and information

- ✓ **Linking and supporting relevant initiatives (coordination/networking)**
- ✓ A sector-led focus group on ground operations has been set up as a result of AHEV

- ✓ **Testing and experimenting with hydrogen electrolizer**
- ✓ Interest building across airports, as hydrogen generation is seen as an important part of the future of aviation
- ✓ Concrete testing at Groningen-Eelde airport
- ✓ Regional subsidies explored regarding hydrogen electrolizer
- ✓ TULIPS: demonstrating GPU and tug on hydrogen (EU funded)

- ✓ **Testing and experimentation of the sustainable TaxiBot**
- ✓ It is estimated that up to 50% of fuel usage during the taxi process can be saved using the TaxiBot

### II. Strategic positioning of hybrid electric technology and innovation

- ✓ **Sustainability certification of airports**
- ✓ Sustainable terminal RTHA (Slim en Duurzaam, NLR)
- ✓ All RSG airports are certified according to ISO 50001 standards

- ✓ **Project BrightSky**
- ✓ Sustainability projects on and around airports, using Schiphol as a testing ground

### III. Execution of programs and projects

- ✓ **Implementation of solar parks at airports**
- ✓ Solar park Schiphol, Eindhoven, Rotterdam-the Hague, Groningen-Eelde
- ✓ GAE
- ✓ Schiphol, Eindhoven and Lelystad have 100% wind energy
- ✓ RTHA has 100% solar power

- ✓ **Green gas implementation**
- ✓ Schiphol Group airports are projected to be off gas by 2030; all other (fossil fuel related) emissions abated
- ✓ Maastricht's terminal is off gas and is working on ACA accreditation

- ✓ **Green transport for people on airside**
- ✓ Currently 53 electric busses are available at AMS airside (100% busses owned by Schiphol)

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# Expected impact of roadmap for Ground Operations is a reduction to almost 0 kt $CO_2$

| Activity | | Current impact | Expected impact 2030 | Requirements and considerations |
|---|---|---|---|---|
| **Electrification of maintenance, handling and sustainable energy for planes** | **Energy for stationary plane** | Roughly ~50% aircraft stands are still serviced by diesel-powered GPUs | 100% of aircraft stands powered by either sustainable grid power or by e-GPUs | • Diesel powered GPU's are being replaced by battery powered eGPU's, because of different operational parameters, the exact replacement ratio is not necessarily 1:1<br>• Availability of enough electricity at airports<br>• Currently there are 5 e-GPUs at Schiphol, 2 at Eindhoven Airport and 3 at Maastricht Aachen Airport |
| | **Heavy equipment** | Owned and leased vehicles: ~1.5 ktCO2[3] | ~0,45 ktCO2[3] | • 100% feasible by 2040 due to natural replacement cycles of equipment and expectation that all heavy equipment is electrified by then<br>• Availability of electric / hydrogen material in all categories of heavy equipment<br>• Improved business case given long depreciation periods<br>• Trained operators |
| | **Light equipment** | Ground Service Equipment: ~25 ktCO2[3] | 0 ktCO2[3] | • Electric alternatives are available for most light equipment<br>• Coordinated effort of complex stakeholder field<br>• Willingness to change despite negative business case<br>• Trained operators |
| **Sustainable energy for buildings** | | Gas consumption: ~18 ktCO2[3] | 0 ktCO2[3] | • Sustainable energy generation infrastructure<br>• Sustainable energy storage<br>• Availability green gas |
| **Sustainable Taxiing** | | ~156-363 ktCO2[1] *(rough estimate: to be validated; explanation on slide 30)* | ~100 – 120 ktCO2 | • Sector capacity requires an updated approach<br>• Investment in TaxiBots or other vehicles<br>• Several TaxiBot operations, trials, demonstrations and studies are planned for the coming years<br>• Ambition to reduce ground emissions as much as possible remains intact |

*Expected impact aligns with goals* | *Expected impact almost aligns with goals* | *Uncertain whether goals can be realized*

 Note: 1) Based on our estimation; 2) NLR; "Slim en Duurzaam"; 3) RSG: Sustaining your world; group-level emissions

# Sustainability of ground operations has a positive outlook

### Sustainable taxiing

- While the TaxiBot has potential, its implementation is complicated due to scope and capacity challenges
- Due to capacity constraints, the timeline for the first operational live trials has been pushed; yet the overall aim to reduce as much ground emissions as possible remains the same
- Schiphol has purchased two TaxiBots from SAS/IAI to accelerate learning about the operation and possible subsequent scale-up
- Several trials and TaxiBot operations are planned later this year and in the upcoming years. These will be accompanied by other studies
- The sector is currently researching how to accelerate scale-up as much as possible after a first standard operation is demonstrated and implemented

**Sustainable taxiing will be reported on in separate communication**

### Electrification of GPUs and equipment

- Recent testing demonstrated diesel powered GPUs can be replaced by mobile e-GPUs or by fixed connections to the power grid. To further reduce use of the aircraft APU, pre-conditioned air will need to be available at aircraft stands
- Heavy equipment will be cycled out due to depreciation and will eventually be replaced by electric or hydrogen material following the general trends in the mobility market. However, this will most likely be after 2030. Accelerating these developments requires significant investments to account for early depreciation
- Part of heavy equipment is not possible to electrify and/or to transition to hydrogen. Currently other measures are explored for abatement
- Light material is transitioning to electricity. As the depreciation times are shorter, replacement will take place before 2030. Due to substantial usage of light material, the total impact on emissions is the largest compared to heavy material
- Light, heavy and stationary equipment should be run on HVO100 if it is not possible to electrify this equipment and to run it on sustainable electricity

**Confidence** in the replacement of the material with electric alternatives. Though the general outlook is positive, the 2030 goals are at risk if limited funds are available

### Sustainable energy supply for buildings

- Buildings at Dutch airports were traditionally gas-powered. Schiphol Group is currently transitioning off gas by 2035, earlier than legislation prescribes
- The roadmap for Schiphol Group to transition to green gas reduces gas consumption from 17,8 ktonCO2 to 2 ktonCO2 by 2030, with 100% abated of the leftover gas consumption set-off by green gas
- Schiphol Group has researched transitioning its buildings to green gas first, before 2030. It was found that it would need to buy such a large volume of green gas, to the extent that it would significantly affect the market price of green gas. Therefore, it was decided to transition mostly to electricity directly, even though this entails longer timelines
- Schiphol, Rotterdam-the Hague and Eindhoven have invested in solar parks. In addition, Schiphol is fully wind-powered, and Rotterdam-the Hague is fully solar-powered. Maastricht Aachen Airport still needs a green electricity contract

**Confidence** in sustainable energy supply for buildings in 2030

### Potential perspectives for government action

1. Stimulate fleet replacement of aircraft handling equipment and support the availability of sufficient charging capacity, including sustainable energy supply and necessary infrastructure
2. Support the working group sustainable taxiing
3. Include Ground Operations development in the Aviation Innovation strategy
4. Monitor the reduction of emissions from Ground Operations

# 4. Appendix

# Technological adoption

To ensure the 2050 ambition is met, hydrogen-electric aircraft must also be considered as a technology enabling emission-free flight

### Advantages of hydrogen-electric aircraft[1]

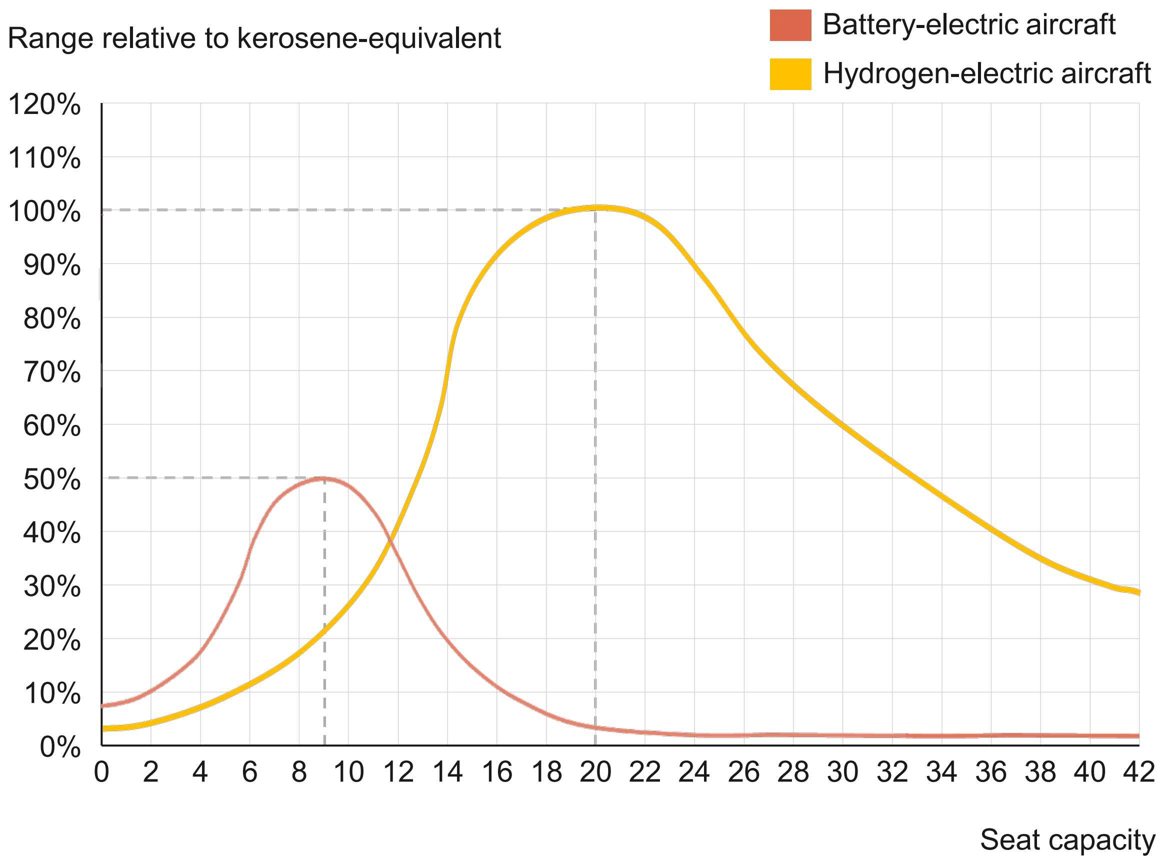
- **Commitment:** Several reputable aircraft manufacturers have committed to developing hydrogen-powered electric aircraft with long-range capabilities and expect them to be operational around 2040

- **Energy density:** Hydrogen has a mass energy density that is 2.8 times higher than gasoline. However, due to its low volumetric density, compressed hydrogen gas requires around six times more volume for the equivalent amount of kerosene

- **Scalability**: With today's technology, 20-passenger hydrogen-electric aircraft can achieve at least the same range as the equivalent kerosene-fueled aircraft, with a gentler drop-off relative to battery-electric aircraft with increasing passenger numbers

- **Feasibility:** Though hydrogen-electric aircraft face similar challenges in terms of certification and qualifications of personnel as battery-electric aircraft, experts believe we could see 80-passenger hydrogen electric aircraft in operation by 2040

### Range relative to kerosene aircraft vs seat capacity (retrofit)[2]




 Source: 1) Expert interviews To70, Unified International; 2) Interpolated from Broekema Aviation - Aircraft Retrofit Market Potential & Social Relevance. Subject to change as technology further develops

# Estimation total emission of taxi to runway in the Netherlands

**Data points and assumptions for a rough estimate:**

- For the sake of this estimation, we assume a ‘common’ aircraft Airbus A320
- For taxiing we assume a fuel flow rate of 0.08 to 0.12 kg/s/engine[1,2]
- Burning jet fuel (kg) converts to three times its mass in $CO_2$ (kg)[3]
- Average taxi time at Schiphol is 9 to 14 minutes (inbound/outbound)[4]
- There are ~600000 total yearly ATMs in the Netherlands[5]
- Other emissions, e.g. from the APU, are not taken into account in this estimate

Estimated total emissions during taxiing in NL = 156 – 363 kt$CO_2$ / year

Total yearly flights = 600000

x

259 – 605 kg of $CO_2$ per ATM

Average taxi time = 9 to 14 mins

x

0.48 – 0.72 kg of $CO_2$ / second

0.08 – 0.12 kg / second /engine jet fuel

x

2 engines on a typical aircraft

x

Jet fuel mass to $CO_2$ mass factor: 3

Source: 1) https://www.easa.europa.eu/en/domains/environment/icao-aircraft-engine-emissions-databank; 2) https://www.mit.edu/~hamsa/pubs/KhadilkarBalakrishnanGNC2011.pdf ; 3) Issue Brief | The Growth in Greenhouse Gas Emissions from Commercial Aviation (2019, revised 2022) | White Papers | EESI 4) https://www.eurocontrol.int/publication/taxi-times-summer-2021 5) https://cbs.nl – for the sake of this estimate we assume all flights taxi similar as on Schiphol airport. While the average taxi time is lower at other airports, over 80% of flights are from/to Schiphol