Market relevance of eRegional Air Mobility in the Netherlands

'Electrification & battery developments for electric flying'-event

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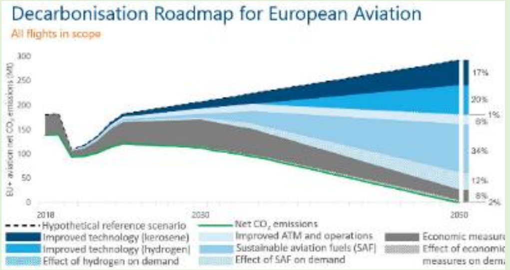
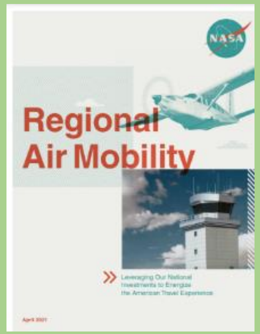
Sustainable aviation is about making air travel more sustainable, but it also entails breakthrough technologies that can play an essential role in a sustainable, efficient and affordable future mobility system

Sustainable Aviation

Aspect	**Key developments**	**Industry initiatives** (example)
Making current air travel more sustainable	• Sustainable Aviation Fuel (very gradual) • Electrification of airport operations • New large aircraft • Increasingly challenging economics	
Leveraging new sustainable aircraft technology to improve regional connectivity	• New (nearly) fully clean propulsion technologies • New small-scale aircraft (with some retrofitting) • New ecosystem with business opportunities • Increasingly attractive economics	

Electric Regional Air Mobility is not THE solution for aviation carbon emissions, but it will be a new way of sustainable and efficient travel for distances up to 750/1000 km and strengthen connectivity of regions

Relevance of zero-emission aircraft

✗ **It is not THE** solution for today's aviation carbon emissions due to the limited range and small size nor will it be able to compete on existing routes with 100+ seater fossil-fuel aircraft

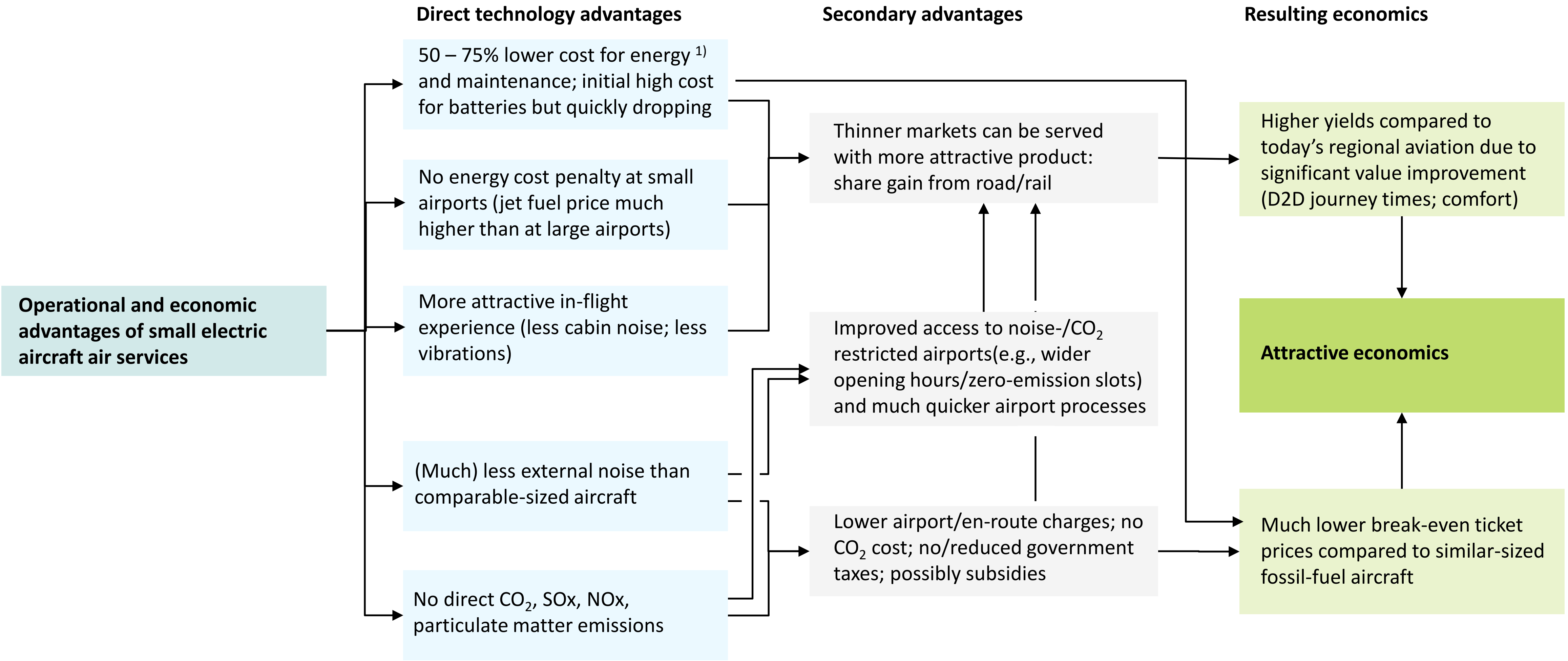
✓ **It is** a completely new, sustainable and attractive way of traveling on distances up to 750 km allowing very significant travel time savings, reducing total journey cost and much improving accessibility of regions.

Advantages

- ✓ No direct emission of CO2, Nitrogen and particulate matter. Low lifecyle CO2
- ✓ Much reduced noise and much safer than car travel
- ✓ Much lower cost for small aircraft making 'thin routes' viable
- ✓ More energy-efficient than electric cars when travelling with less than 3 persons in the car; equal to rail
- ✓ Abundant capacity at regional airports with very low cost to prepare for electric aviation

The attractive economics of electric regional air services are driven by improvements in direct cost, comfort and emissions which will enhance market access and yields compared to today's regional air services

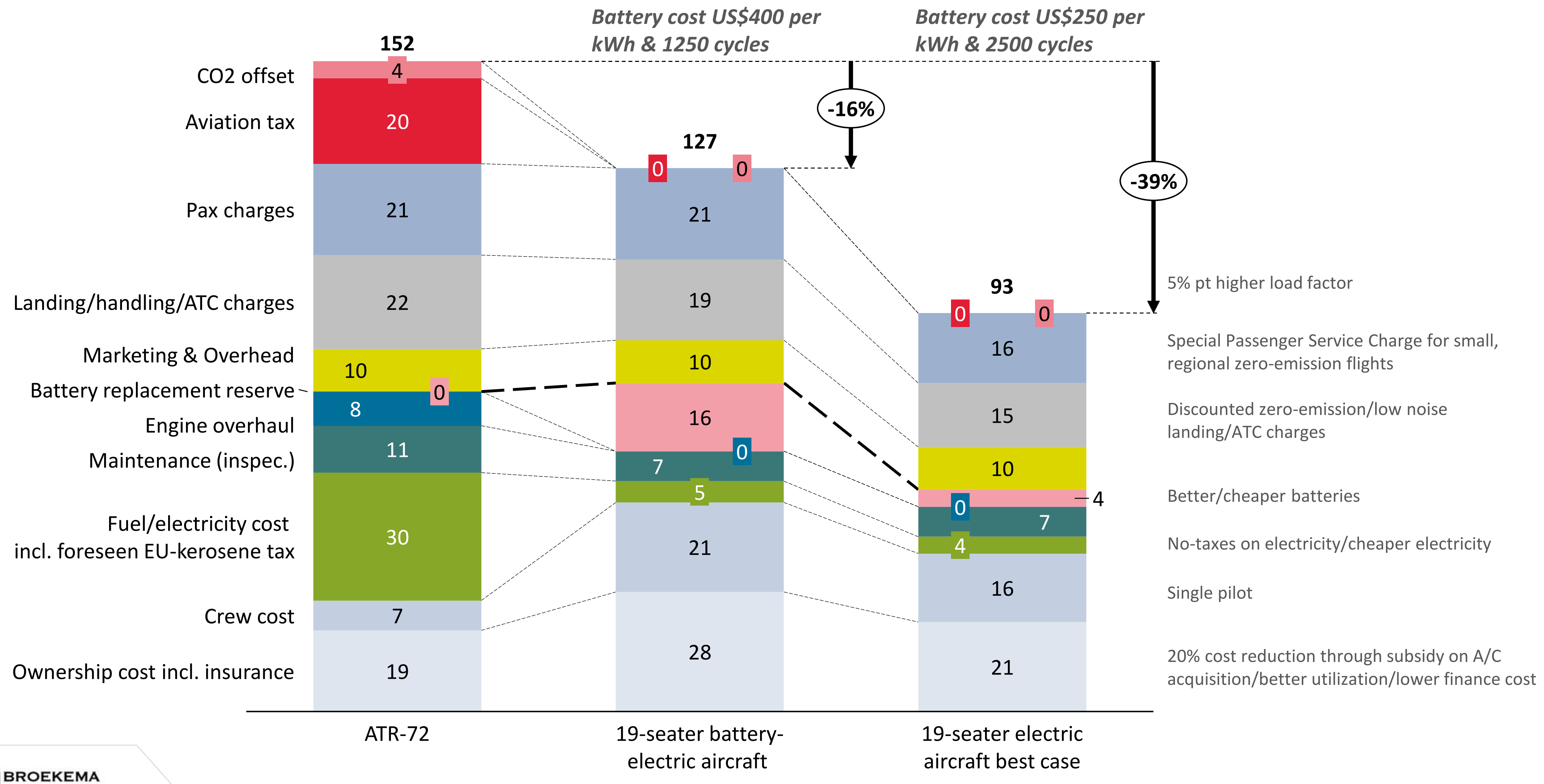
OVERVIEW OF ELECTRIC AVIATION ECONOMICS VIS-À-VIS CURRENT TECHNOLOGY



Energy cost advantage strongest for battery-electric aircraft and hybrid-electric aircraft. Hydrogen energy cost will be higher than fossil fuel cost today for the foreseeable future but with kerosene tax and SAF blending, will still be an attractive business case

An battery-electric 19-seater has relatively high ownership and crew cost compared to a 70-seater fossil aircraft but compensates this with significant savings on energy, maintenance, airport cost and reduced taxes

Bottom-up estimate of trip cost per passenger in EUR for a 400 km route from the Netherlands (assuming new aviation tax level not applied for electric aircraft)



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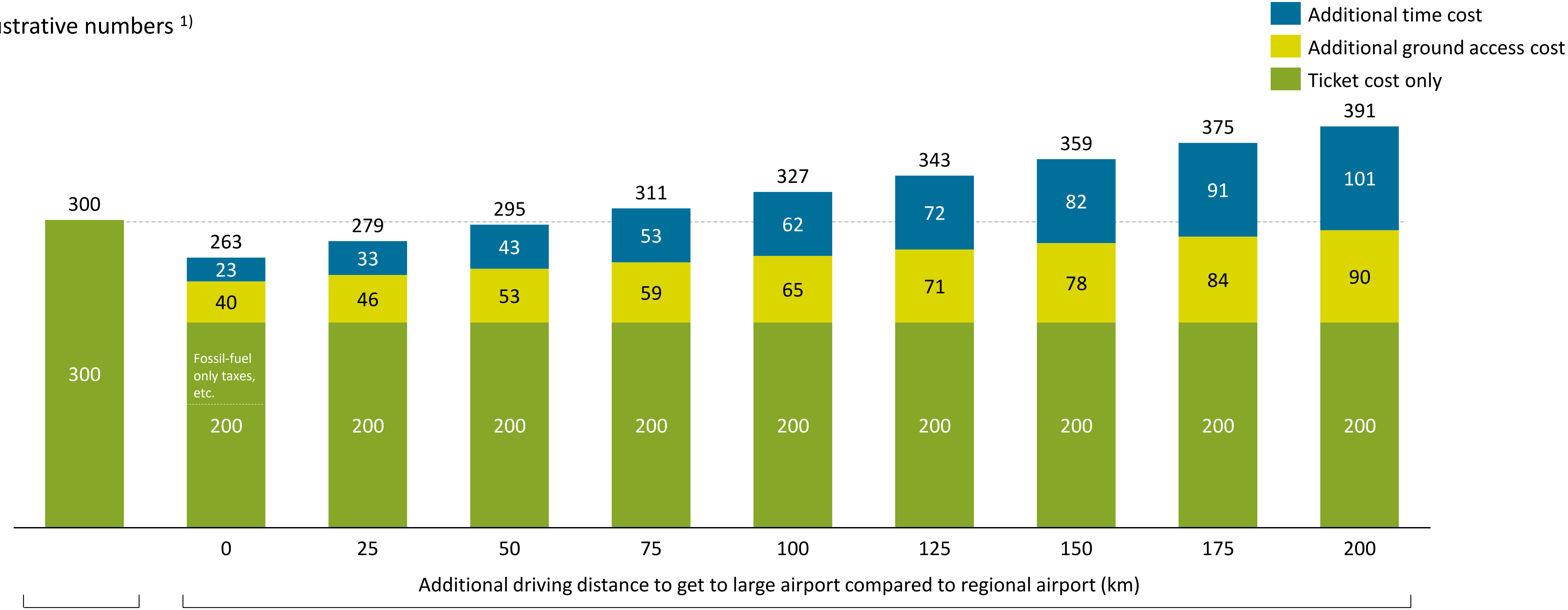
Note: jet fuel cost at regional airports typically much higher than at large airports making fossil-fuel operations less profitable. With electricity no such differences exist

Source: M3 analysis based on extensive bottom-up modelling of cost, travel time, energy consumption and emissions using January 2022 data and Maastricht/Groningen airport charges

The competitiveness of high(-er) price eCTOL flights from regional airports strongly improves the further away passengers have to travel to a large airport to catch a lower price narrowbody flight

Differences in total journey cost by additional distance to get to a large airport compared to flying from nearby regional airport , EUR

Illustrative numbers [1)]



eCTOL ticket cost from regional airport

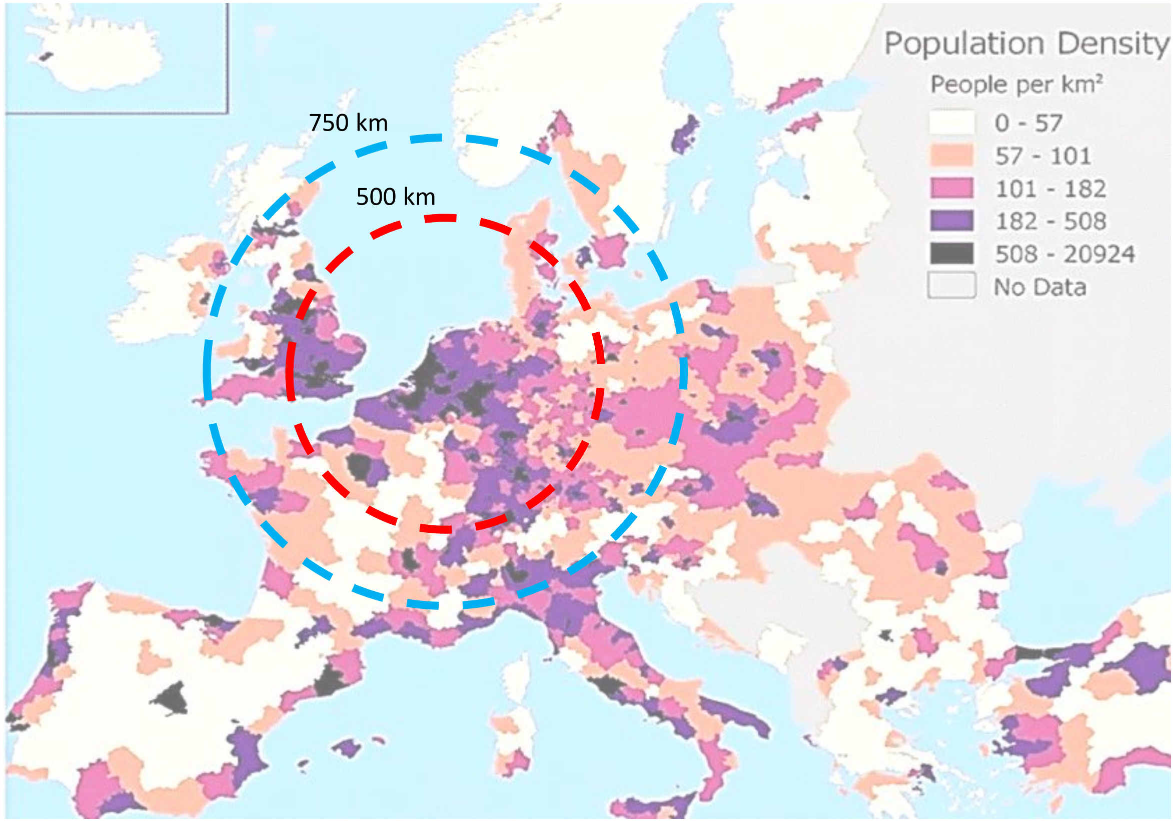
Narrowbody aircraft (Boeing 737/Airbus A320s) total travel cost from large airport

1) Assuming value of time of EUR 35 per hour; 30 min additional flying time for eCTOL compared to narrowbody; EUR 40 difference in cost for 2-day parking at large airport vs. regional airport; road access average speed of 90 km/h and EUR 0.25 variable cost per km. Airport time with eCTOL: 20 min; narrowbody 90 minutes

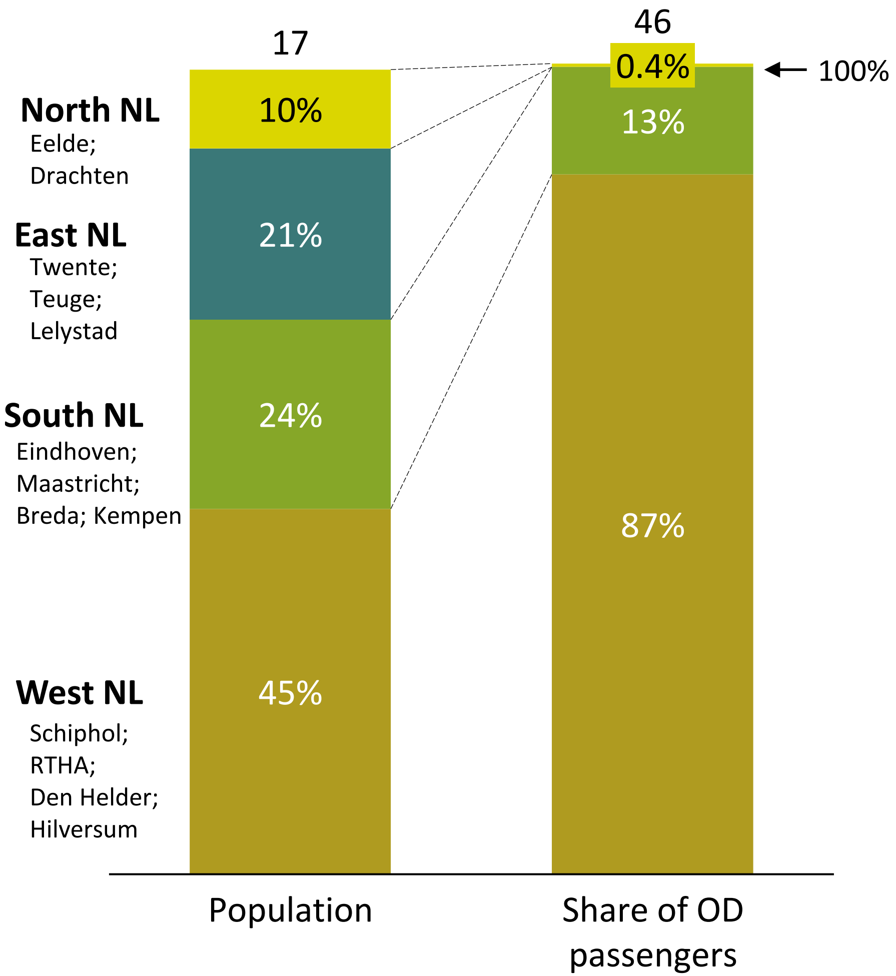
Sources:

The market opportunity for eRAM services from Dutch regional airports is very high given the high population density in surrounding countries and a currently strong concentration of air travel in West NL

EU population density by NUTS-regions, 2020



Share of total population and of 2019 airport passengers* by part of the Netherlands

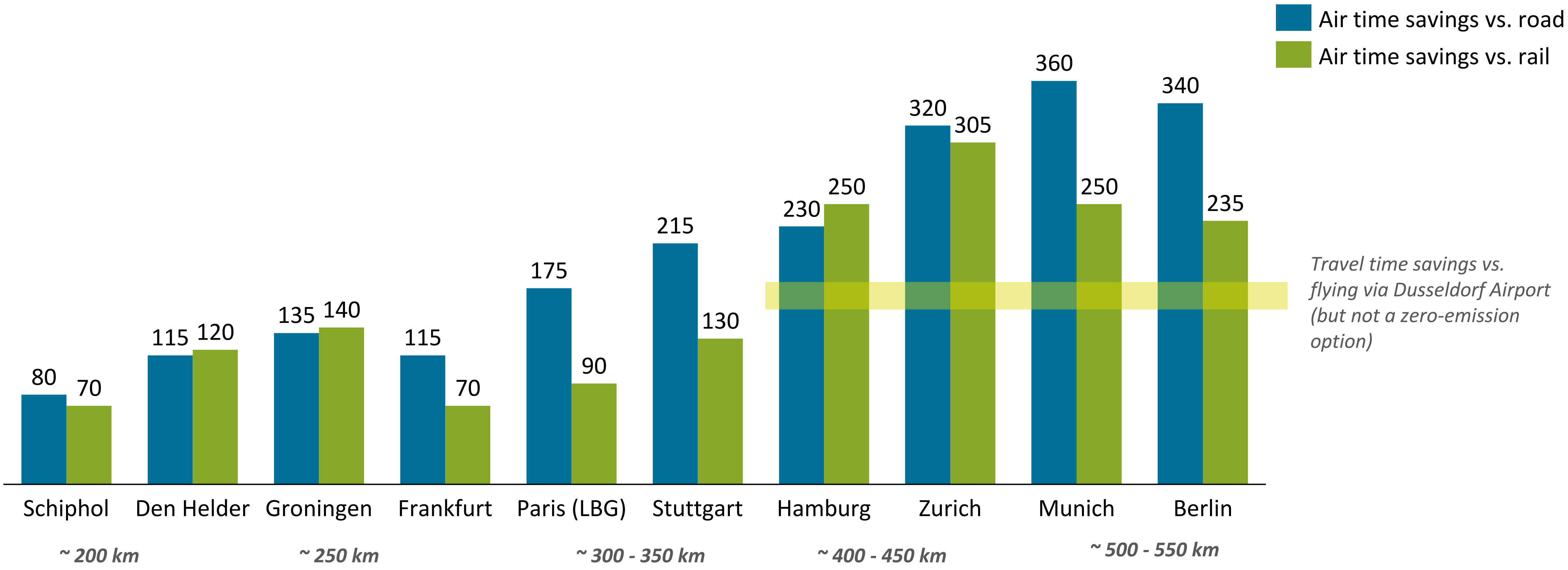


* Excluding transfer passengers

Source: "Gamechanger in EU demography: Working-from-home economy: Juric (2021); airport statistics; CBS

Time savings that can be achieved by eRAM services from regional airports can easily add up to 2 to 3 hour even on <400 km routes

Potential door-to-door journey time savings in minutes from Maastricht City center of taking an eRAM flight vs. travel by road and rail



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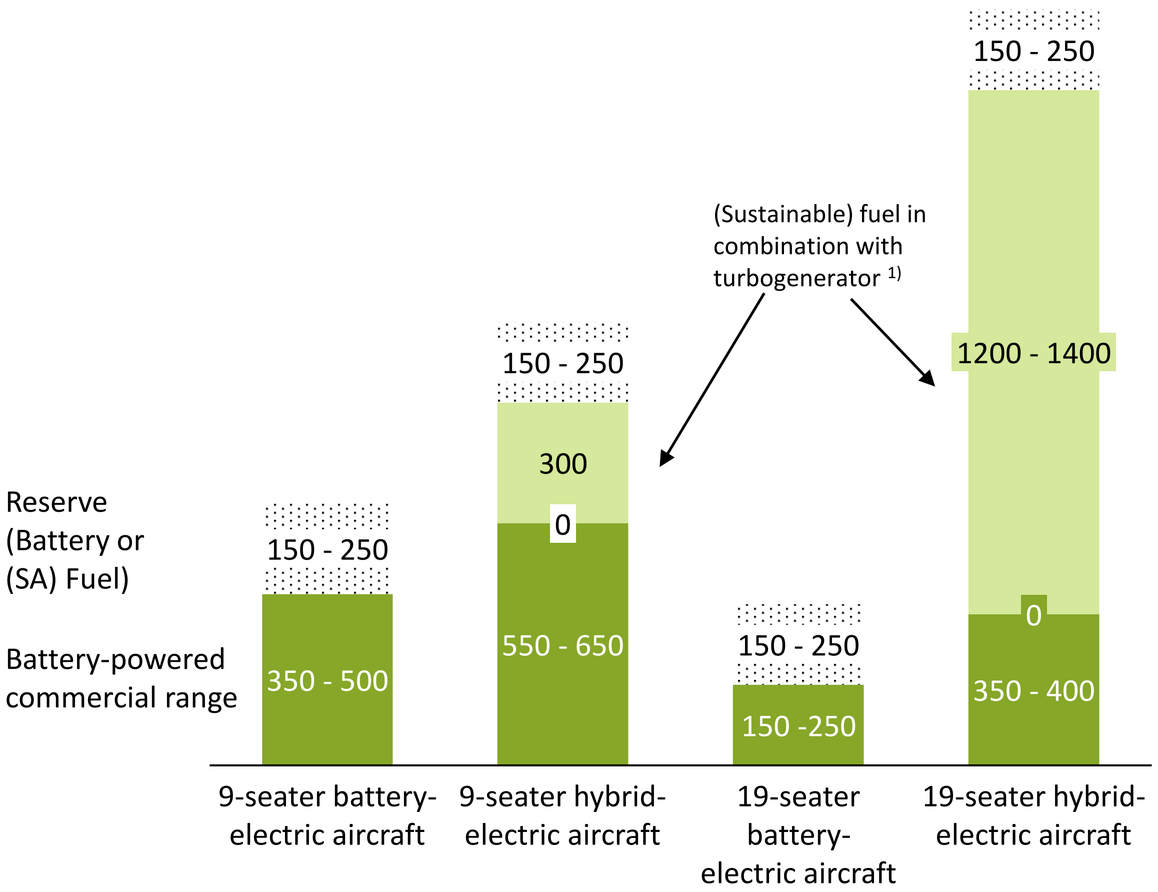
Source: M3 analysis using Google Maps and flight planning tool

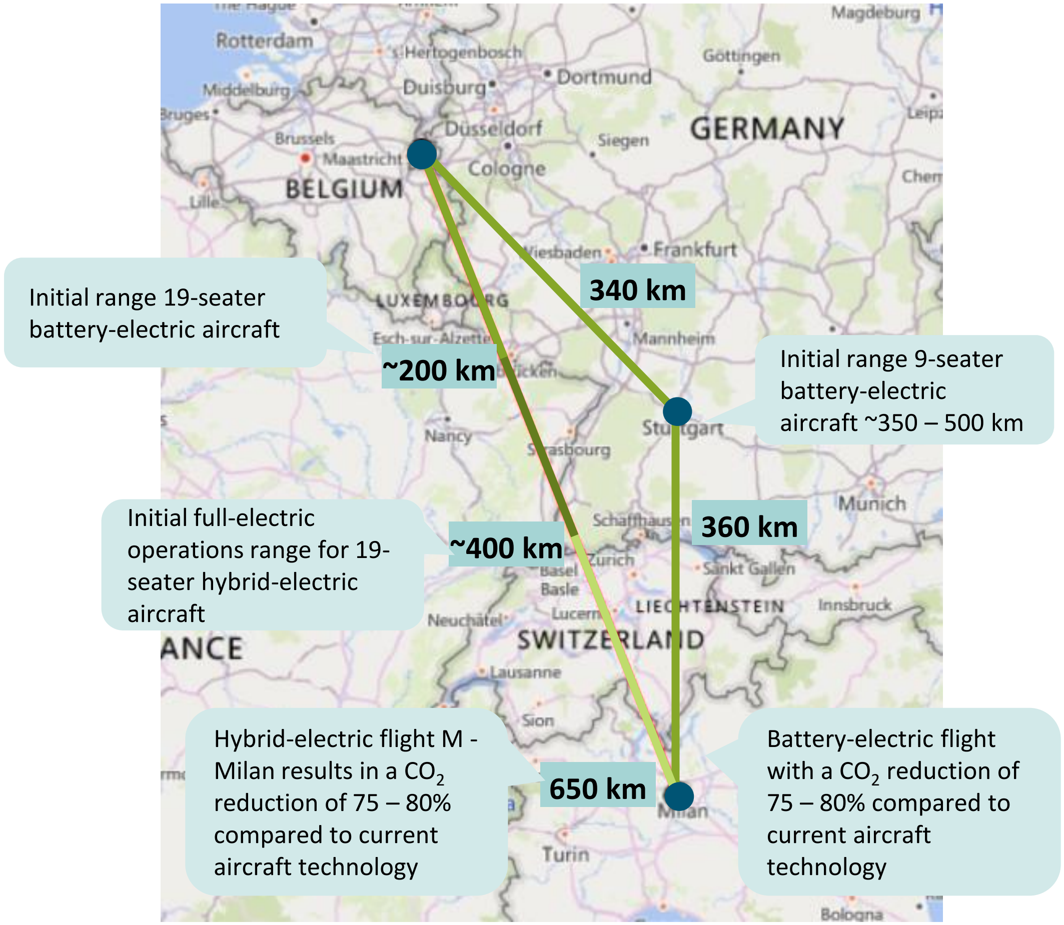
Destinations beyond 400 km can be covered by making an intermediate stop or by hybrid-electric technology achieving still very significant CO2 reductions

Practical range of battery-electric and hybrid-electric aircraft: pure battery powered-range vs. maximum range

Estimated range of a 9 and 19-seater battery-electric and 19-seater hybrid-electric aircraft with battery pack energy density of ~ 220 – 240 Wh/kg in kilometre



Flight options to service a hypothetical route Maastricht Aachen Airport to Milan Linate airport



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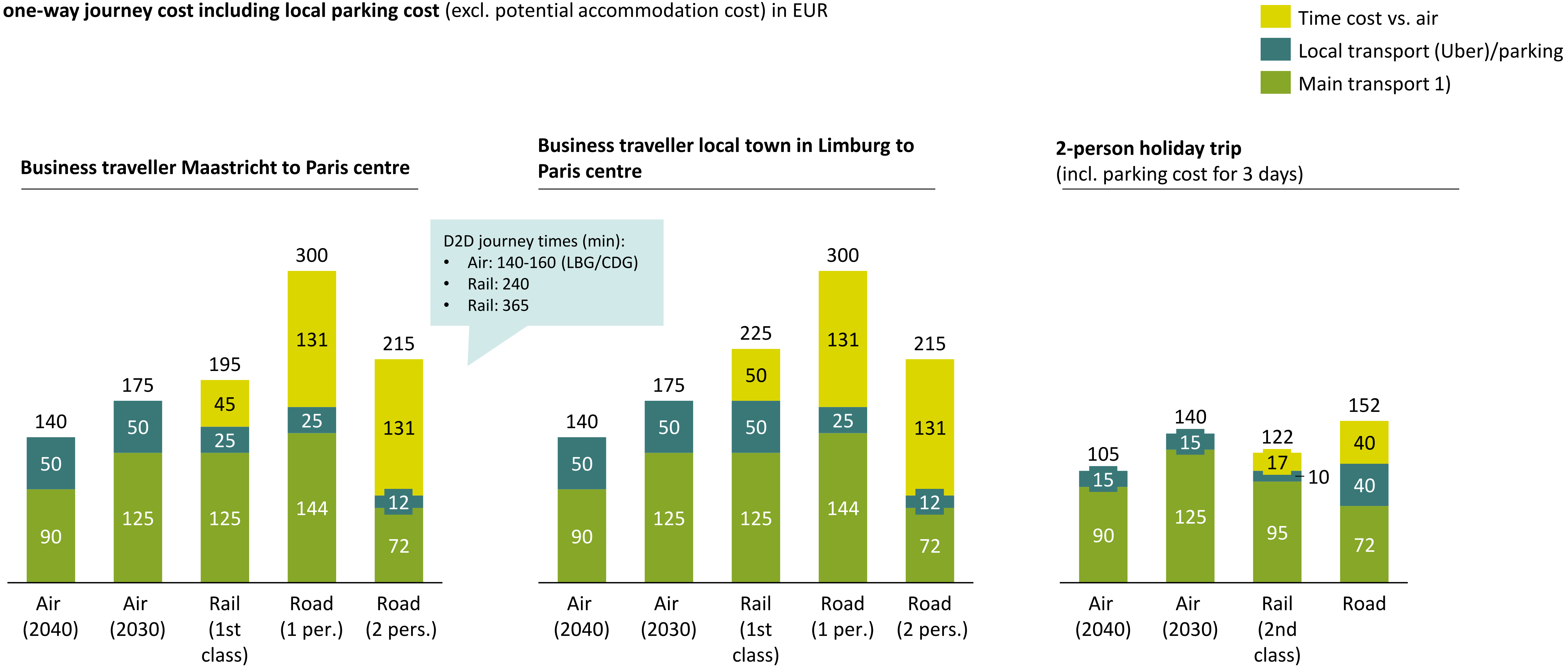
[1] Range with regular/sustainable fuel can vary significantly depending on aircraft design

Source: M3/GH Consulting analysis based on extensive OEM and technology assessments

Cost vs. other modes of travel: Case example Maastricht – Paris: eCTOL already competitive for business travellers in 2030 and by 2040 also for leisure travellers

Total one-way journey cost including local parking cost (excl. potential accommodation cost) in EUR



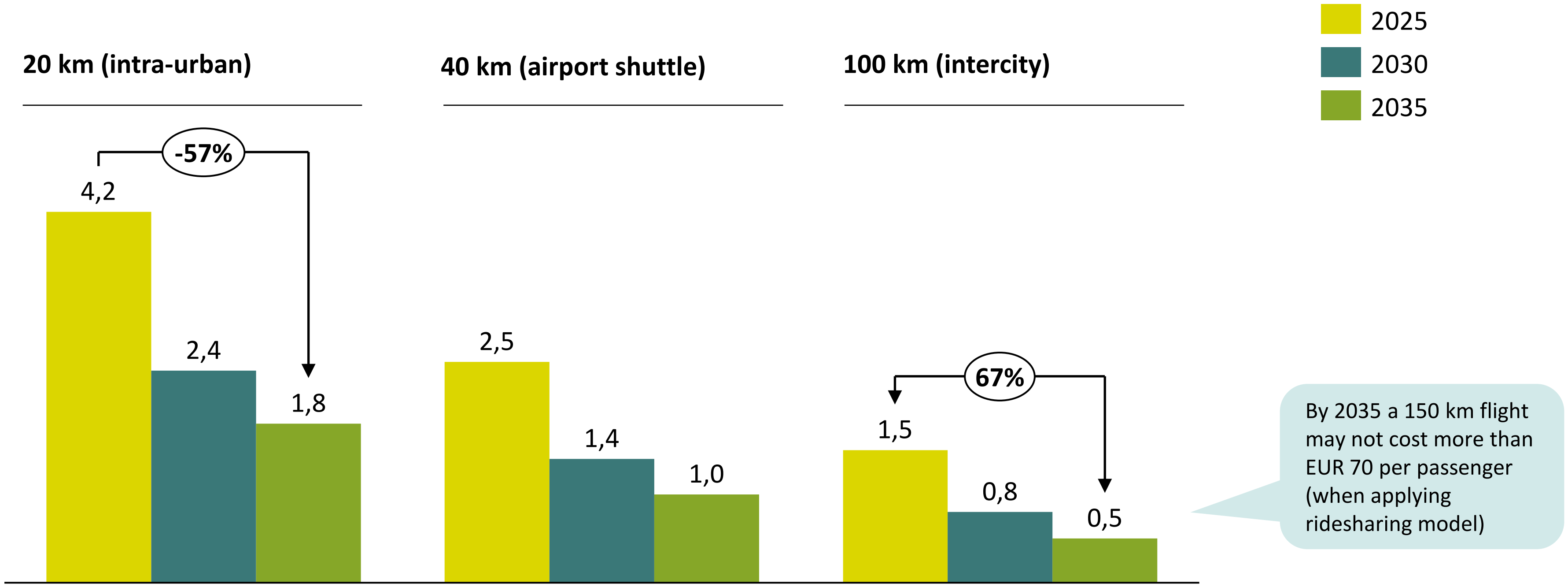
1) Air travel prices include airline profit margin and EUR 15 in passenger/security fees; road price is EUR 0.23 + 0.07 road pricing; rail is one-way price as available for Feb 2022. Local transport cost based on Uber-like fare (EUR 1.75 per km) . Assumed value of time rail travel EUR 25; car travel EUR 35

2) Rail is currently indirectly subsided with approx. EUR 0.10 per pkm (due to rail infra cost being mostly paid by the government)

Source: DLR SAT tool; NIBUD; NS.nl; Google Maps; M3 analysis

The price per passenger kilometer for eVTOL will drop significantly on longer distances and over time

Estimated price per passenger km on an eVTOL, in 2021 euro



Assumed average pax/flight	2.0 (LF 50%)	*2,2 (LF 55%)*	2,4 (LF 60%)

Main drivers for cost savings over time:

- Battery cost (more cycles, lower prices)
- Higher utilization and load factor
- Simplified pilot training/autonomous (allowing also more passengers)
- Scale economies of production

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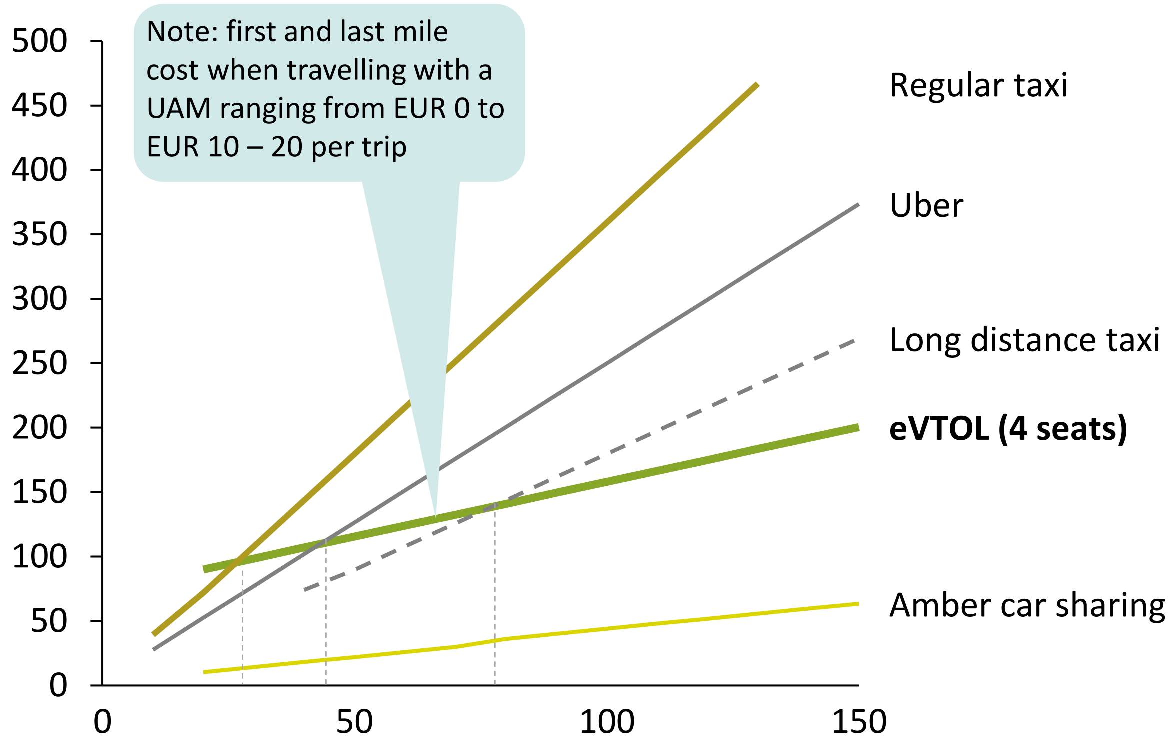
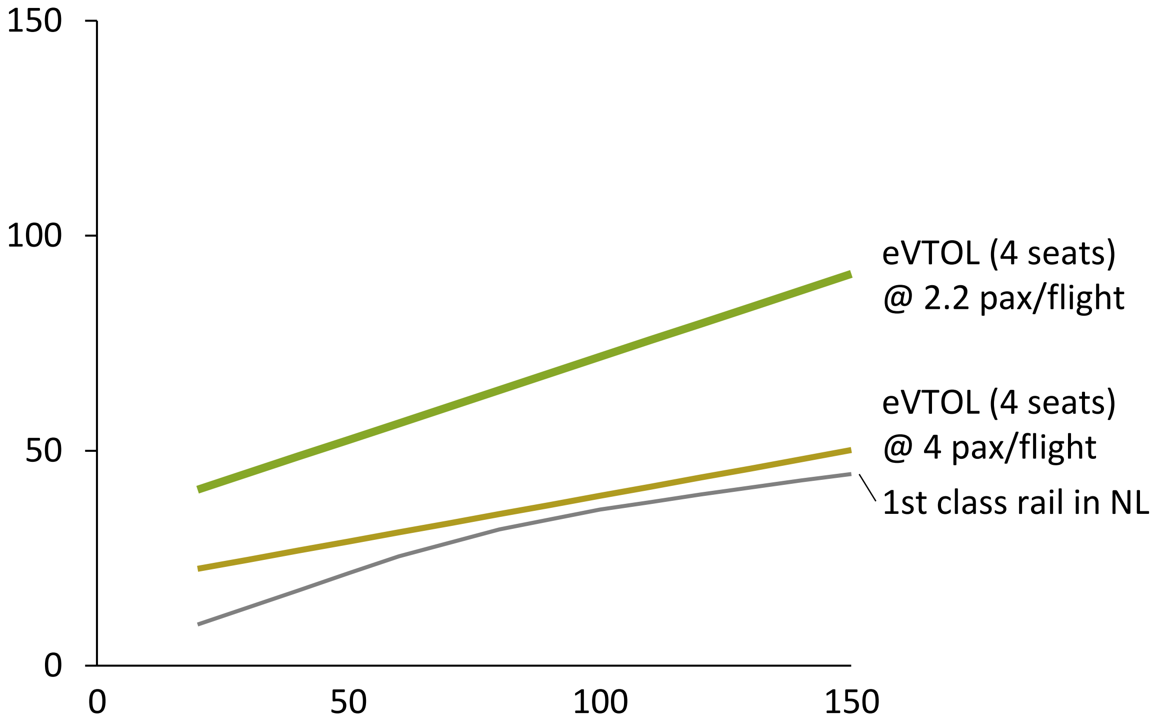
Source: M3/PEN EM analyses

Given the low variable price per km, *vehicle* trip cost for a UAM service is by 2030 expected to beat taxi services from around 30 – 50 km while on a per passenger basis is ~ twice as expensive as first-class rail

Estimated *vehicle trip cost* in 2030 expressed in 2021 EUR for different modes



Estimated *passenger trip cost* in 2030 expressed in 2021 EUR for different modes



Average load factor

Source: M3 UAM cost model

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The combination of eCTOL and eVTOL technologies is expected to allow for many new connections from regional airports: example Maastricht Aachen Airport

Examples of potential eCTOL routes initial stage (2030-2035) **and later stage** (2035-2040)

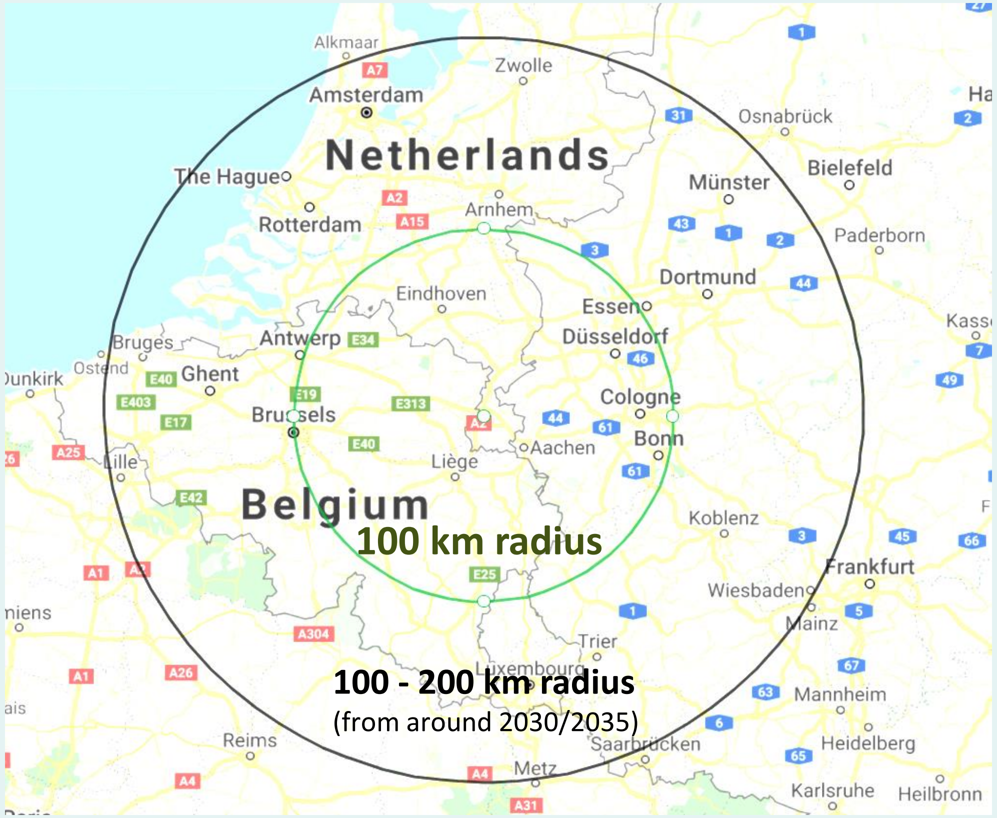
Initial stage
(max range
~ 450 km)

Second stage network
(max range
750 km)

***Examples* of potential eVTOL destinations initial** stage (2030-2035) **and later stage** (2035-2040)

Initial stage: Dusseldorf; Antwerp; Brussels; Cologne/Bonn; Eindhoven; Venlo

Second stage: Breda, The Hague; Amsterdam; Zwolle; Enschede; Arnhem; Lelystad; Ghent; Luxembourg; Dortmund; Munster



Note: this network development is constrained by availability of eVTOLs; vertiport network development and global scale (unit price of eVTOLs)

A multitude of technologies (eVTOL, eSTOL and eCTOL) for manned- and unmanned cargo aircraft is coming to the market which will unlock new logistics chains/same-day services

Source: OEM

	eVTOL (fully autonomous)		**eSTOL** (initially piloted)	**eCTOL** (pilot and autonomous)	**Fossil-fuel cargo drones**
	Last mile delivery	***Small shipments***	***Feeder remote locations***	***Feeder flows***	***Cargo hub-to-hub flows***
					
Runway/space required	~5 x ~5 meter	~30 x ~30 meter	~100 – 150 meter	Up to 800m	Up to 2000 m
Typical range	-20 – 50 km	500+ km	500 – 700 km	500 - 750 km	>5000 km
Examples (payload/ range)	• VoloDrone (200 kg/40km) • Flyingbasket (100 kg) • Xi'anSupersonic Aviation (100 kg)	• Pipistrel Nuuva V300 (hybrid-electric, 460 kg/typical range 300 km) • Elroy Air Chapparal (226 kg/482 km) • Sabrewing Rhaegal RG-1 (450 kg/580 km)	• Airflow (900 kg/800 km) • Dufour Aero 3	• Eviation Alice Cargo • Xwing (retrofit Cessna Caravan 206) • Hydrogen cargo conversion of large turboprop aircraft	• Natilus (up to 100 tonnes; transpacific capabilities) > 50% lower trip cost compared to Boeing 747 Freighter but 2-3 times longer trip time
Expected entry into service	• First commercial services started	• 2022 - 2024	• 2023 - 2025	• 2023 - 2027	• 2025+

With today's aircraft technology the cost for air cargo is 8 – 10 times higher than for road cargo. In addition, cargo is relatively less time-sensitive. However, these new technologies, especially when autonomous and with high energy-dense battery-electric propulsion may narrow that can to a factor of 1.5 to 3 towards 2035/2040. With less risk of congestion and issues with truck-driver shortages, this segment will likely to become a relevant option for current logistics flows as well as trigger new logistics flows

Power Up: an initiative lead by regional airports in the Netherlands aiming to accelerate the introduction of low/zero emission Regional Air Mobility in the Netherlands

Rotterdam The Hague Airport
MAASTRICHT AACHEN AIRPORT
EindhovenAirport
GRONINGEN AIRPORT EELDE
Schiphol Group
nlr
KLM
m3

Summary of Power up ambition, actions and stakeholder collaboration

Background and ambition	• The four main regional airports in the Netherlands with support of Royal Schiphol Group and other partners have launched the Power Up initiative aimed at facilitating and accelerating eRegional Air Mobility (eRAM) in the Netherlands. The underlying driver is a firm belief in the significant societal value eRAM can bring especially to regions
Actions launched	• Following an extensive process of feasibility studies and market consultation in 2021, the airports have now defined a set of 4 ambitious actions related to the operations of new eRAM services. This includes a strongly coordinated approach to ensuring required facilities and procedures are in place well ahead of certification of the first eRAM aircraft and a distinctive passenger journey
Collaboration with OEM/Operating partners and sponsors	• Power Up now aims to expand its collaboration by transforming into an open source-accelerator for OEMs/Operators who can benefit from the favorable operating conditions for testing and launching new services. Other stakeholders are invited to become a sponsor supporting the introduction while also benefitting from access to knowledge and marketing opportunities