Electrification of aviation: Accelerating the transition

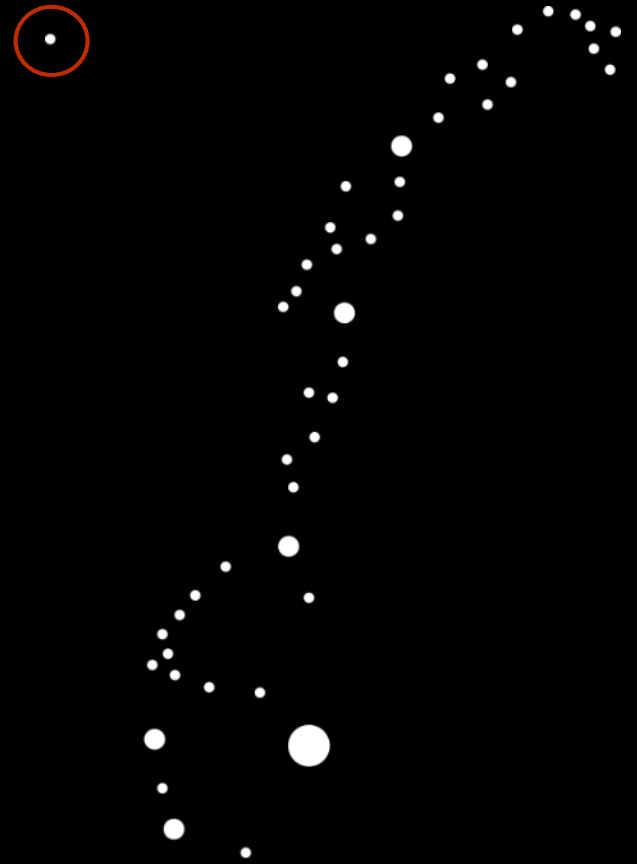
Sustainable Aviation? Digital seminar
Western Norway University of Applied Sciences (HVL)
07 OCT 2020

Olav Mosvold Larsen, Avinor

44 airports

Norway’s Air Navigation Service Provider

Norway is totally dependent on aviation



AVINOR

Paris Agreement

1.5 – 2 ºC

80-95% emission reduction by 2050

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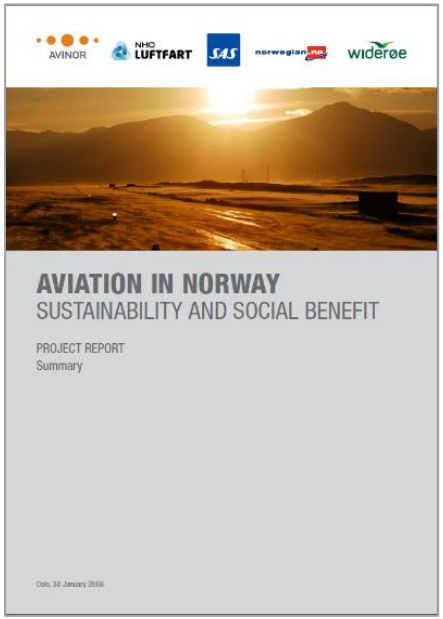
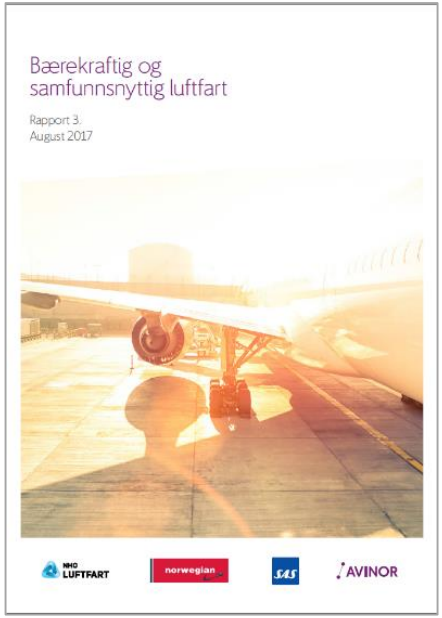
BE SURE TO WASH YOUR HANDS AND ALL WILL BE WELL
COVID-19
RECESSION
CLIMATE CHANGE

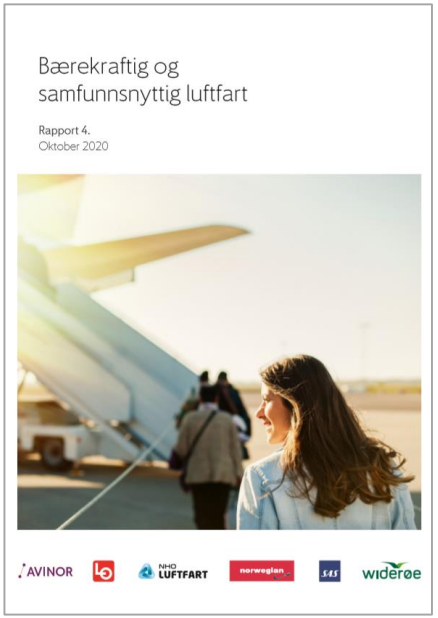


2008

2011



2017



2020

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Norwegian aviation fossil free by 2050
(No fossil fuels will be used on flights within and from Norway from 2050)
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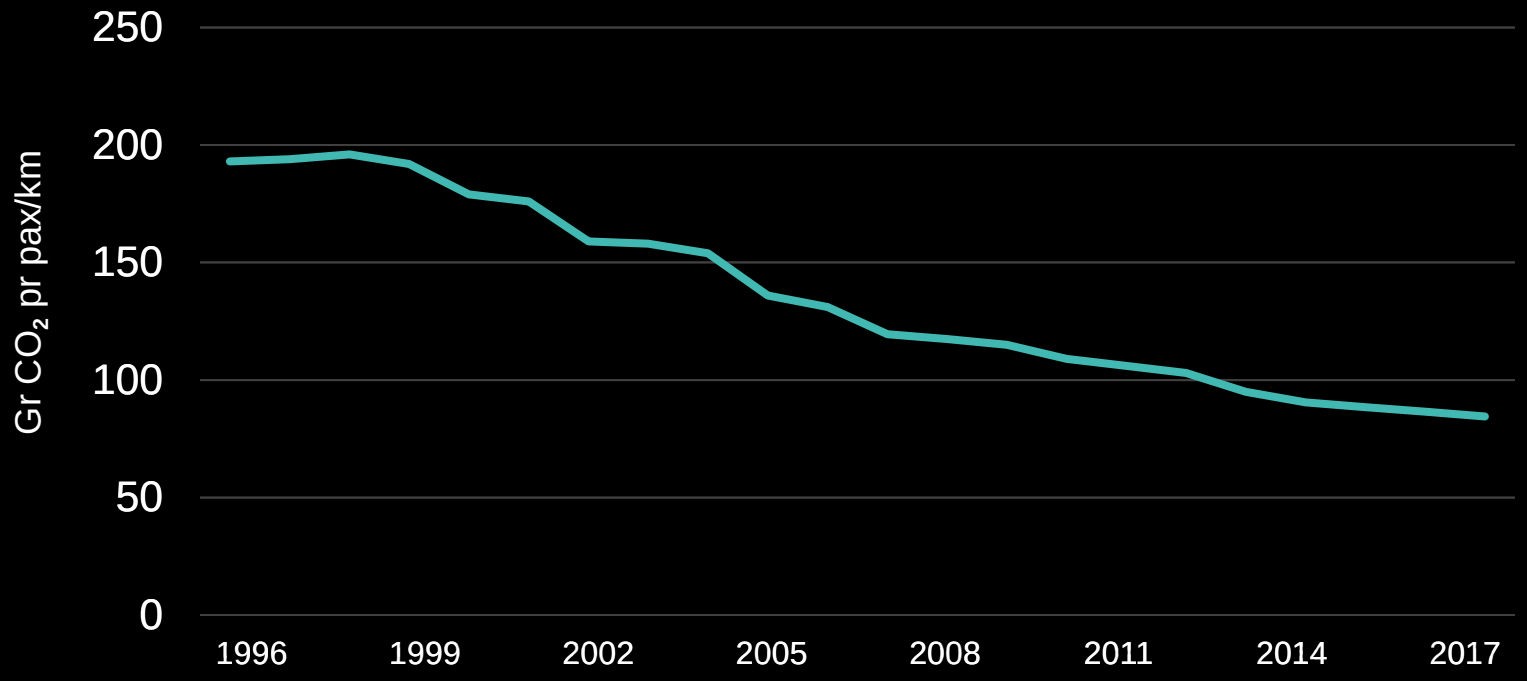
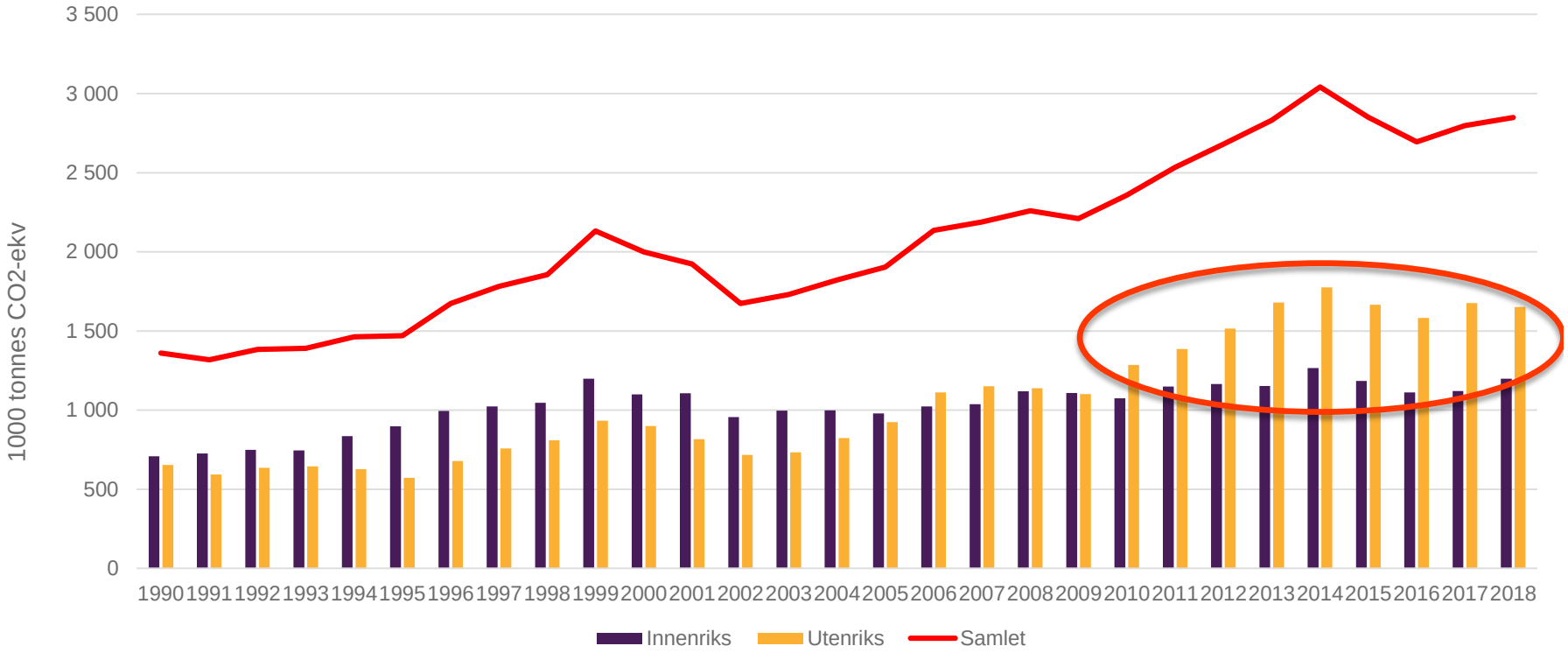
Emissions per passenger km decreasing



Average SAS and Norwegian

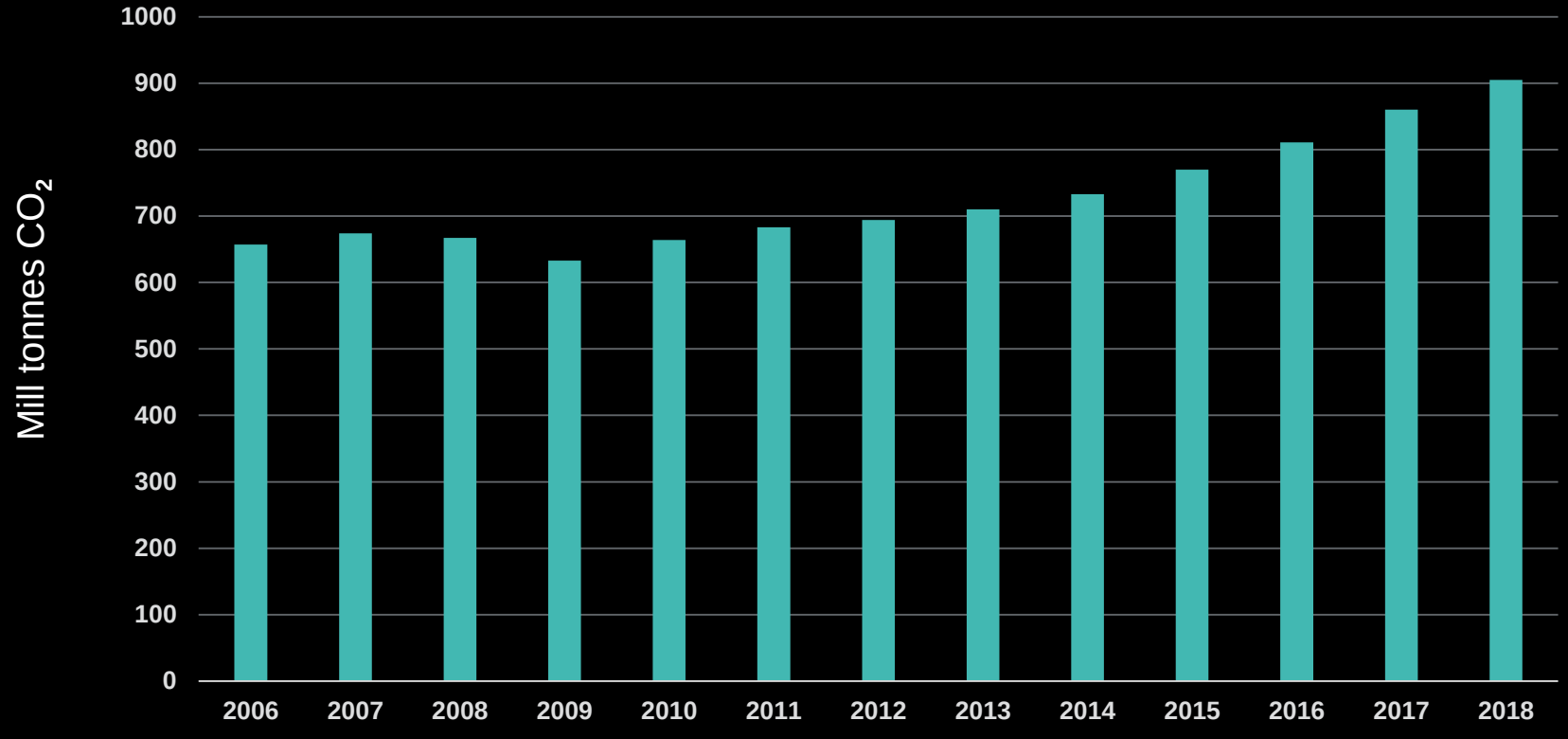
GHG EMISSIONS CIVIL AVIATION NORWAY 1990-2018



(I tillegg kommer effekten av utslipp i høye luftlag)

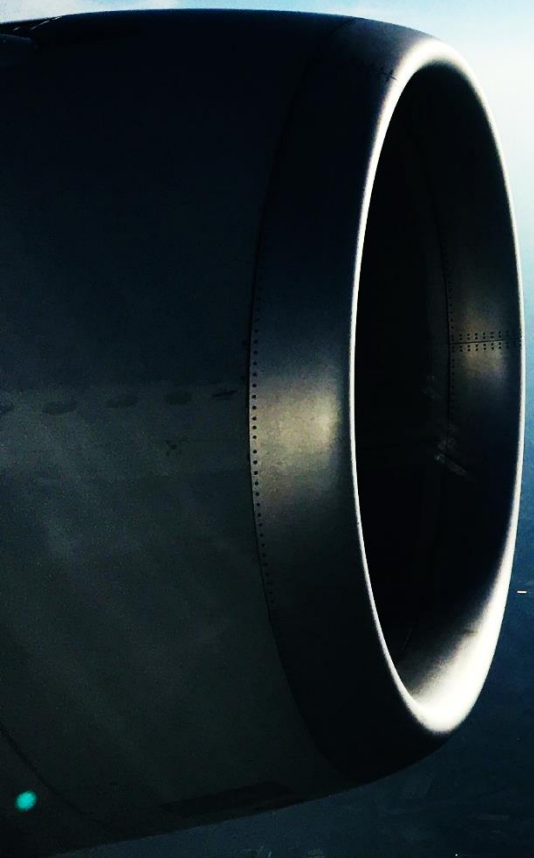
AVINOR

Air traffic total emissions worldwide increasing

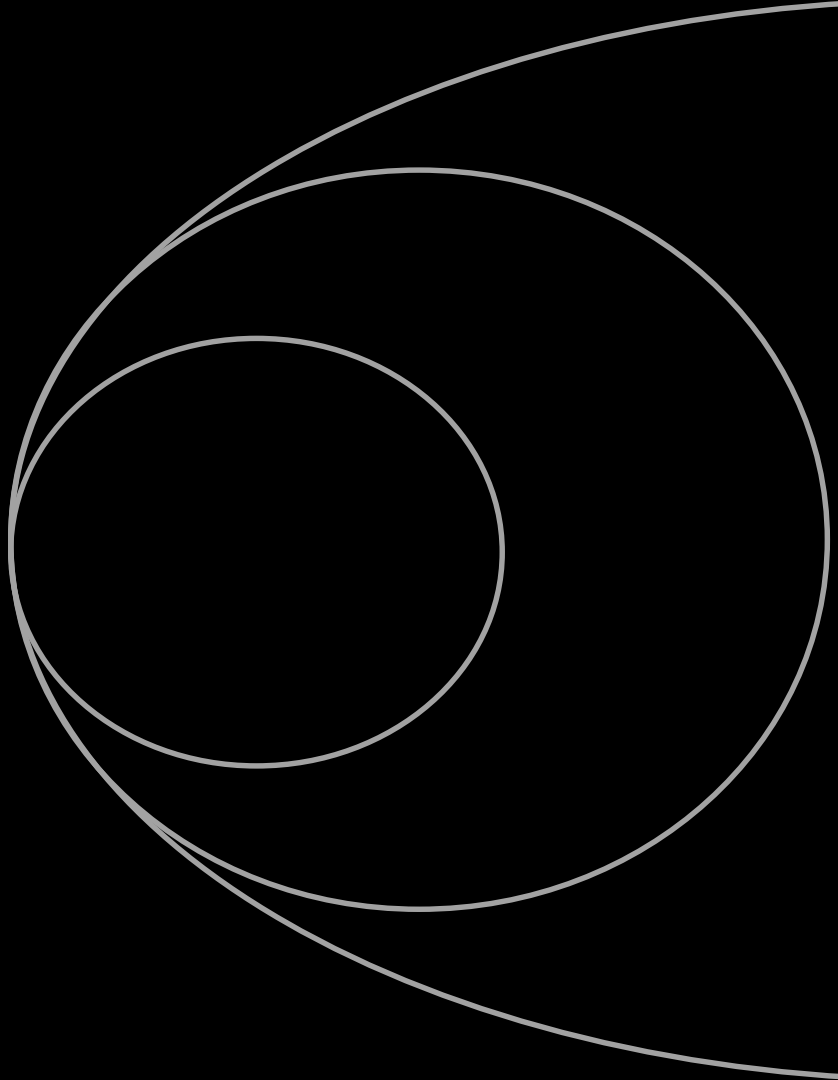


Source: IATA

Aviation emission reductions



- More energy efficient aircraft
- Sustainable Aviation Fuels (SAF)
  - Jet biofuels
  - E-fuels
- New technologies
  - Electrification
  - Hydrogen



Time frame: 2030 (?)

- ➔ Short haul: Battery electric (small aircraft)
  - Energy efficient!
- ➔ Regional: Hybrid electric and/or fuel cell
  - Short routes can be flown 100% electric
  - Share of hydrocarbons
- ➔ Long haul: SAF (= non fossil hydrocarbons)
  - Jet biofuel
  - e-fuel

Sustainable Aviation Fuels (SAF)

- 2009: Certified
- Pro: Can be dropped into current aircraft and infrastructure
- Con: Production low – price high
- 2014: First SAF flights in Norway
- 2016-2018: A limited volume available at Avinor’s airports in Oslo and Bergen
- 2020: Drop-in mandate of 0.5% advanced biofuels in Norway. Political goal of 30% by 2030

Electrification

Battery

Parallell hybrid
Serial hybrid

Fuel cell | H2

Electric motor



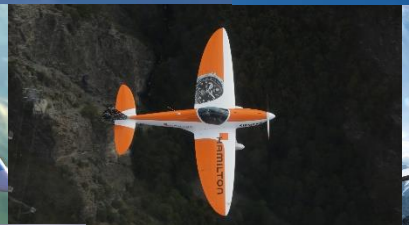
Rolls-Royce

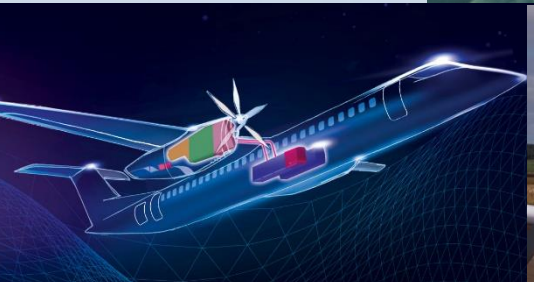
N72342







easyJet

HAMILTON


EMBRAER


ELECTRIC
DEMONSTRATOR
EMBRAER

E10


CriCri 2010

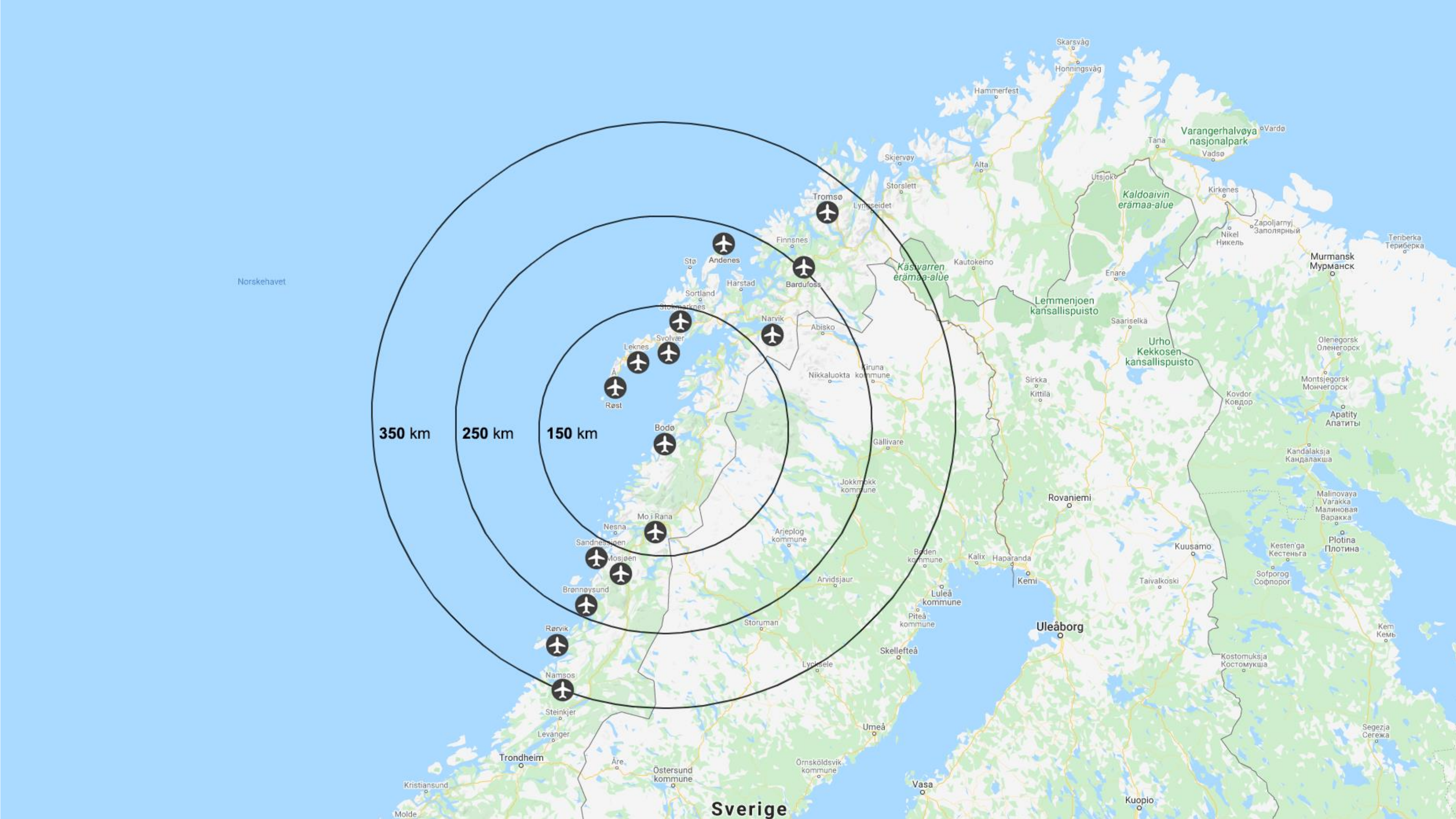
Airbus E-Fan 1.1
Crossed the English Channel 2015

Pipistrel Alpha Electro (2018)

- Empty weight: 382.5 kg
- Maximum take-off weight: 560 kg
- Cruising speed: 85 Kts (157 km/h)
- **Range: 70 NM (130 km) + 20 % reserve**
- Battery: 21 kWh (20 kWh usable)
- Charging: up to 400V/32A

www.avinor.no/elfly


Leknes
Svolvær
104 km
109 km
Røst
Bodø
102 km
101 km
Mo i Rana



350 km
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Norskehavet
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Bodø
Mo i Rana
Nesna
Sandnessjøen
Mosjøen
Brønnøysund
Rørvik
Namsos
Steinkjer
Levanger
Trondheim
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Östersund kommune
Sverige
Abisko
Kiruna kommune
Nikkaluokta
Gällivare
Jokkmokk kommune
Arjeplog kommune
Arvidsjaur
Boden kommune
Luleå kommune
Piteå kommune
Storuman
Skellefteå
Lycksele
Umeå
Örnsköldsvik kommune
Vasa
Kalix
Haparanda
Kemi
Uleåborg
Rovaniemi
Kuusamo
Taivalkoski
Kuopio
Sirkka
Kittilä
Kautokeino
Käsivarren erämaa-alue
Lemmenjoen kansallispuisto
Saariselkä
Urho Kekkosen kansallispuisto
Enare
Kaldoaivin erämaa-alue
Utsjoki
Skarsvåg
Honningsvåg
Hammerfest
Skjervøy
Storslett
Alta
Lyngseidet
Tana
Varangerhalvøya nasjonalpark
Vadsø
Vardø
Kirkenes
Nikel
Никель
Zapoljarnyj
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Мурманск
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Olenegorsk
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Montsjegorsk
Мончегорск
Kovdor
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Malinovaya Varakka
Малиновая Варакка
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Кестеньга
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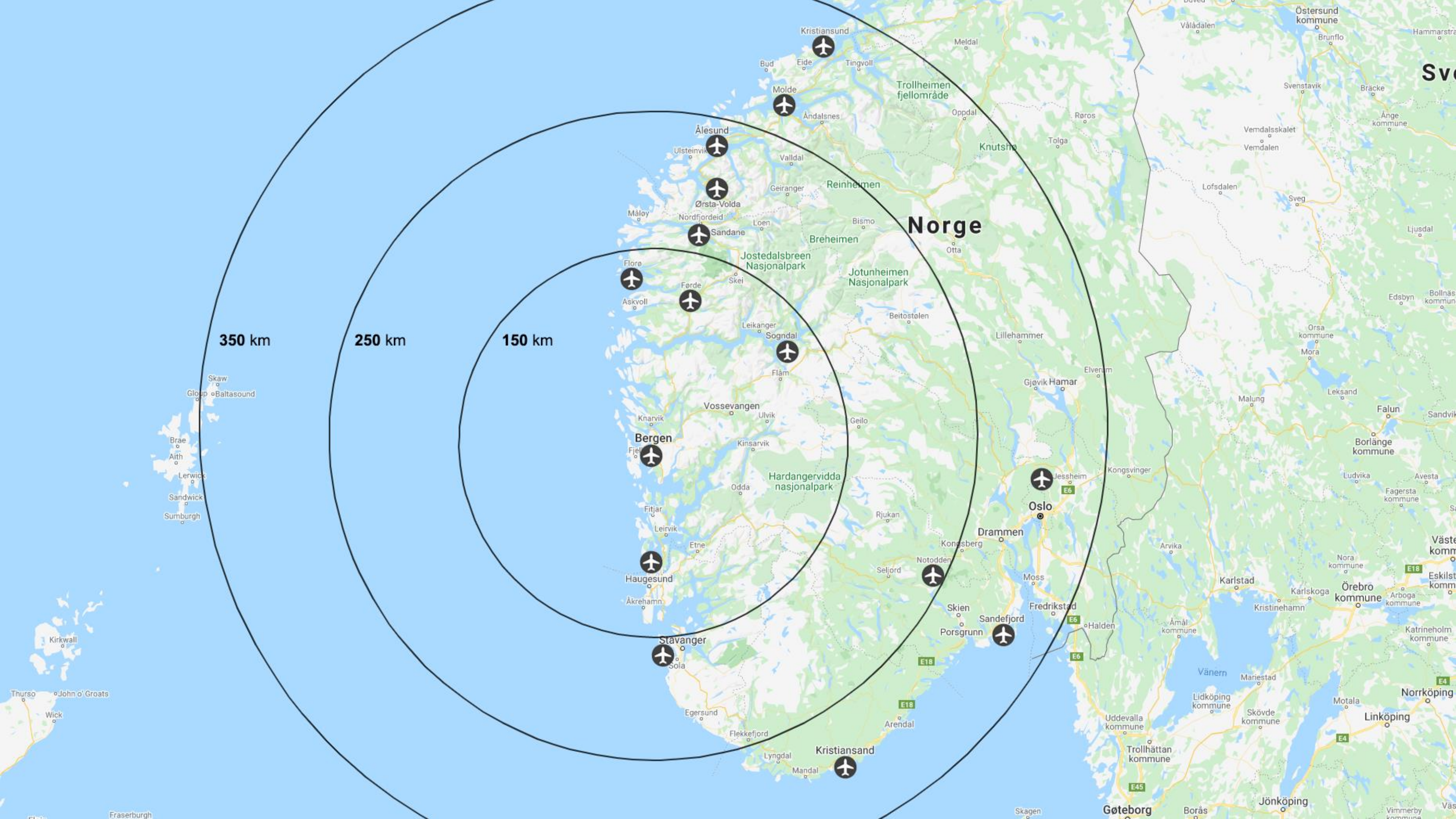
Костомукша
Segezja
Сегежа

Heart Aerospace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Trollheimen fjellområde
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Oppdal
Røros
Tolga
Knutshø
Ålesund
Ulsteinvik
Valldal
Geiranger
Reinheimen
Ørsta-Volda
Måløy
Nordfjordeid
Loen
Bismo
Sandane
Breheimen
Otta
Jostedalsbreen Nasjonalpark
Jotunheimen Nasjonalpark
Florø
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Skei
Askvoll
Beitostølen
Leikanger
Sogndal
Lillehammer
Flåm
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Hamar
Elverum
Vossevangen
Ulvik
Geilo
Knarvik
Bergen
Kinsarvik
Hardangervidda nasjonalpark
Odda
Jessheim
Kongsvinger
Oslo
Fitjar
Rjukan
Leirvik
Drammen
Etne
Kongsberg
Notodden
Seljord
Haugesund
Moss
Åkrehamn
Skien
Fredrikstad
Sandefjord
Porsgrunn
Halden
Stavanger
Sola
E18
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Arendal
Flekkefjord
Kristiansand
Lyngdal
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Kirkwall
Thurso
John o' Groats
Wick
Fraserburgh
Skagen
Göteborg
Östersund kommune
Vålådalen
Brunflo
Hammarstrand
Sve
Svenstavik
Bräcke
Ånge kommune
Vemdalsskalet
Vemdalen
Lofsdalen
Sveg
Ljusdal
Edsbyn
Orsa kommune
Mora
Leksand
Malung
Falun
Borlänge kommune
Ludvika
Avesta
Fagersta kommune
Arvika
Nora kommune
Karlstad
Karlskoga
Örebro kommune
Kristinehamn
Arboga kommune
Åmål kommune
Vänern
Mariestad
Lidköping kommune
Skövde kommune
Uddevalla kommune
Trollhättan kommune
Motala
Linköping
Norrköping
Jönköping
Borås
E45
E4
E18


Svalbard
Longyearbyen
Honningsvåg
Mehamn
Berlevåg
Båtsfjord
Hammerfest
Vardø
Hasvik
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Lakselv
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Tromsø
Sørkjosen
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Stord
Notodden
Haugesund
Sandefjord
Stavanger
Kristiansand

AVINOR

Short RWY network in Norway:
74% of all flights shorter than 300 KM

- 88 Citypairs < 100KM
- 140 Citypairs < 150KM
- 183 Citypairs < 200KM
- 249 Citypairs < 300KM
- 290 Citypairs < 400KM
- 310 Citypairs < 500KM
- 337 Citypairs < 1041km

widerøe

ZeroAvia

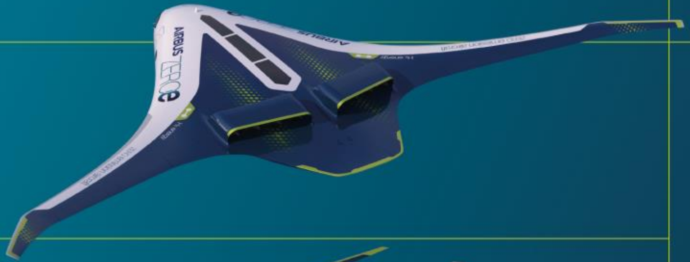

AIRBUS

Introducing Airbus ZEROe

Turboprop

- **<100** Passengers
- **1,000+nm** Range
- Hydrogen Hybrid Turboprop Engines (x 2)
- Liquid Hydrogen Storage & Distribution System

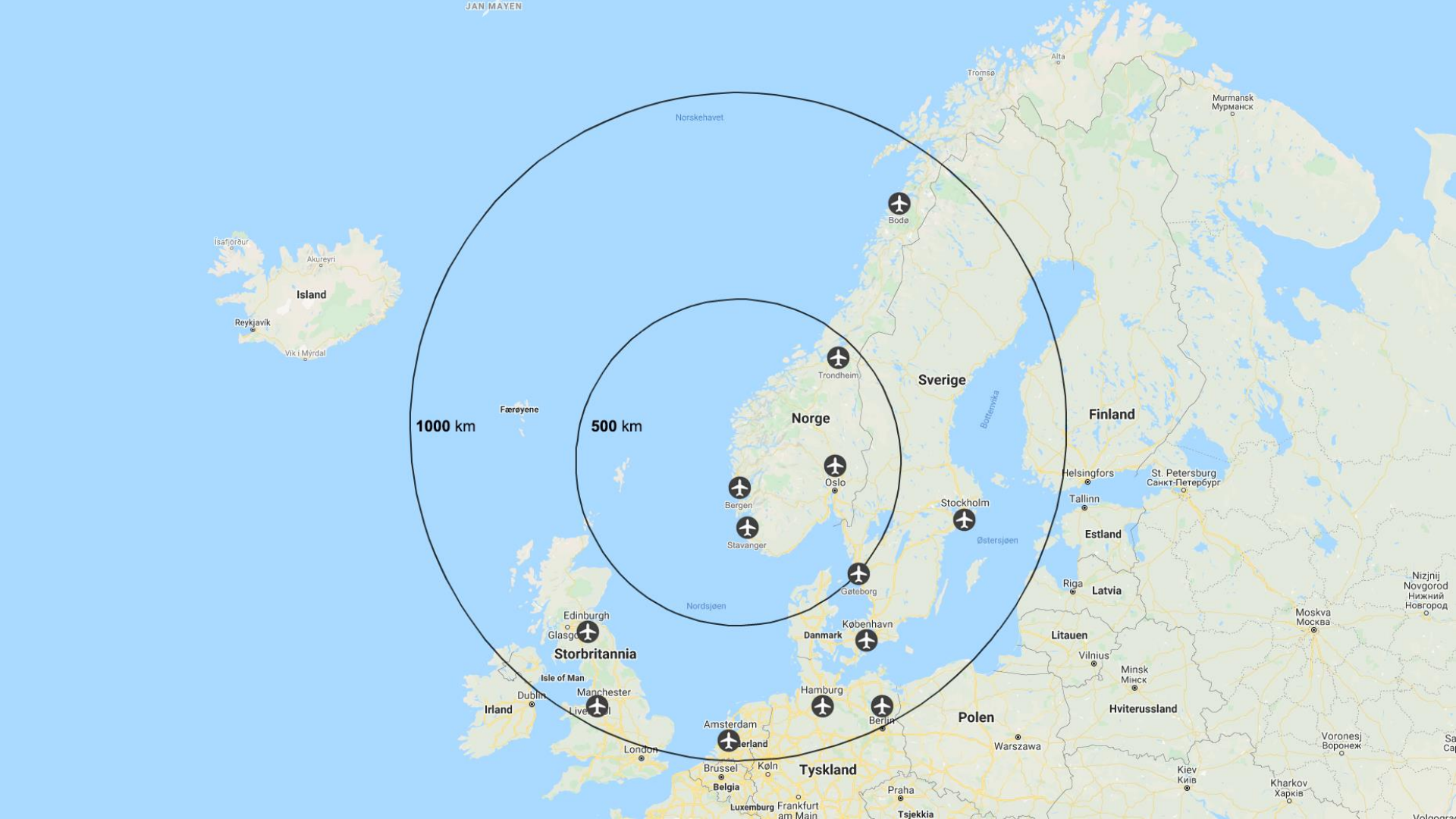
Blended-Wing Body



Turbofan

- **<200** Passengers
- **2,000+nm** Range
- Hydrogen Hybrid Turbofan Engines (x 2)
- Liquid Hydrogen Storage & Distribution System

AIRBUS


1000 km
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Færøyene
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Trondheim
Norge
Sverige
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Bergen
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Helsingfors
St. Petersburg
Санкт-Петербург
Tallinn
Estland
Riga
Latvia
Litauen
Vilnius
Minsk
Мінск
Hviterussland
Moskva
Москва
Nizjnij Novgorod
Нижний Новгород
Bottenviken
Østersjøen
Nordsjøen
Göteborg
København
Danmark
Storbritannia
Edinburgh
Glasgow
Isle of Man
Irland
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Luxemburg
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Praha
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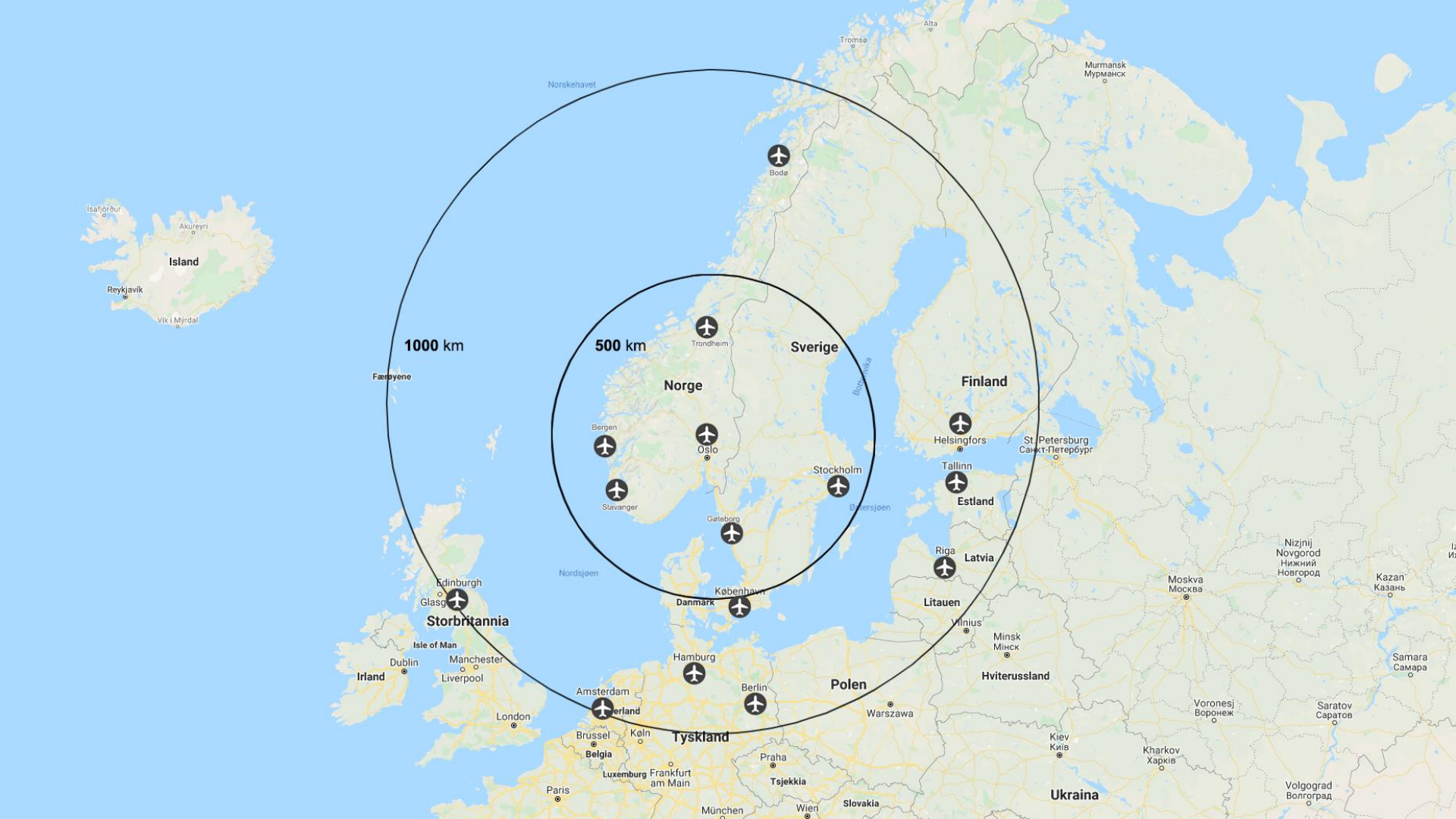
Tromsø
Alta
Murmansk
Мурманск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Frankfurt am Main
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Wien
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Ukraina
Kiev
Київ
Kharkov
Харків
Voronesj
Воронеж
Saratov
Саратов
Volgograd
Волгоград

H2

- Fuel cell = electrified aircraft
- Sustainable Aviation Fuels (hydrotreatment)
- E-fuels (carbon + H2 electrolyzed)
- Direct combustion (Cryogenic?)

➔ Massive H2-efforts world wide

Forslag til program for introduksjon av elektrifiserte fly i kommersiell luftfart

Trondheim, 5. mars 2020

Luftfartstilsynet

AVINOR

Summary of reccommended goals, measures and instruments

Goals

- Norway will be a driving force and arena for the development, testing and early implementation of electrified aircraft
- By 2030, the first ordinary domestic scheduled flights will be operated with electrified aircraft
- By 2040, all civil domestic aviation in Norway will be operated with electrified aircraft, reducing greenhouse gas emissions by at least 80% compared with 2020

Technological development

- International innovation cooperation
- National coordination
- Innovation arena/centre in Norway
  - Collective expertise
  - Access to infrastructure and airspace
  - Financial support for testing and development

Risk mitigation

- Grants for charging infrastructure
- Support scheme for purchase of aircraft
- Possible State guarantee concerning residual value
- VAT exemption for light aircraft

Operation

- Requirements for routes covered by a public service obligation (with grant scheme)
- Exemption from air passenger duty
- Exemption from VAT on tickets for air travel
- Reduced electricity tax for charging of aircraft
- Reduced aviation charges (evaluated in accordance with EU regulations)

CONSEQUENCES FOR AVINOR'S INFRASTRUCTURE?

- Mapping electricity capacity on Avinor's airports
- Looking into innovative and flexible charging solutions
- Or will fuel cells/H2 be the preferred solution?

CONCLUDING REMARKS

- Norway is totally dependent on aviation
- Green House Gas emissions must be mitigated
- Airlines investing in more energy efficient aircraft
- Sustainable aviation fuels already available
- Electrified passenger aircraft will be a reality
- Hydrogen is part of the solution

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