
SUSTAINABLE AVIATION IN NORDIC COUNTRIES

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TRV 2023/33078
Regionalt Hållbart flyg för Norra Europa

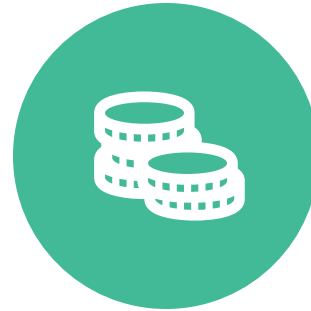
GENERAL ASPECTS



ENVIRONMENTAL



SOCIAL



ECONOMIC



TECHNOLOGY

SUSTAINABLE AVIATION

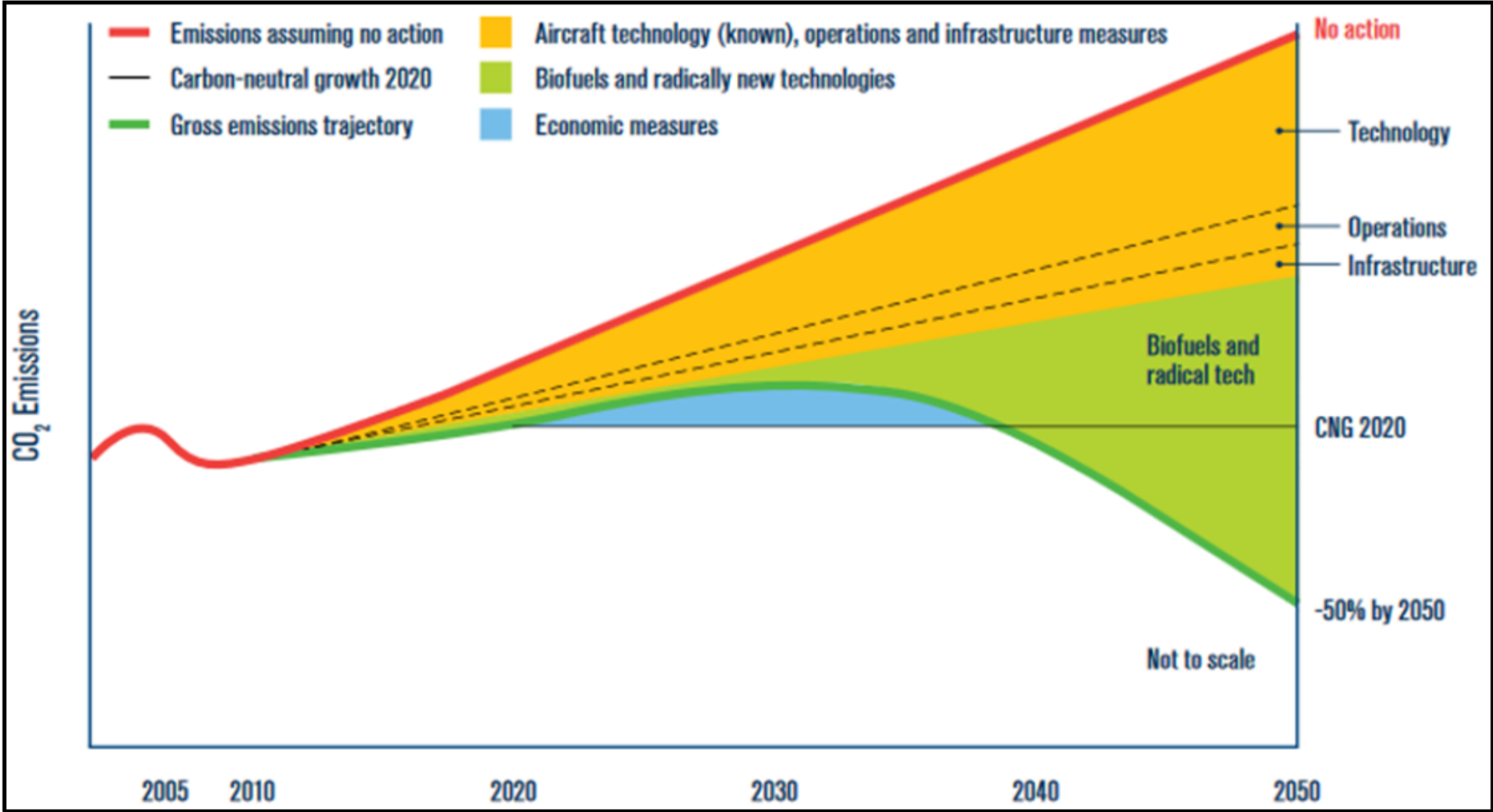
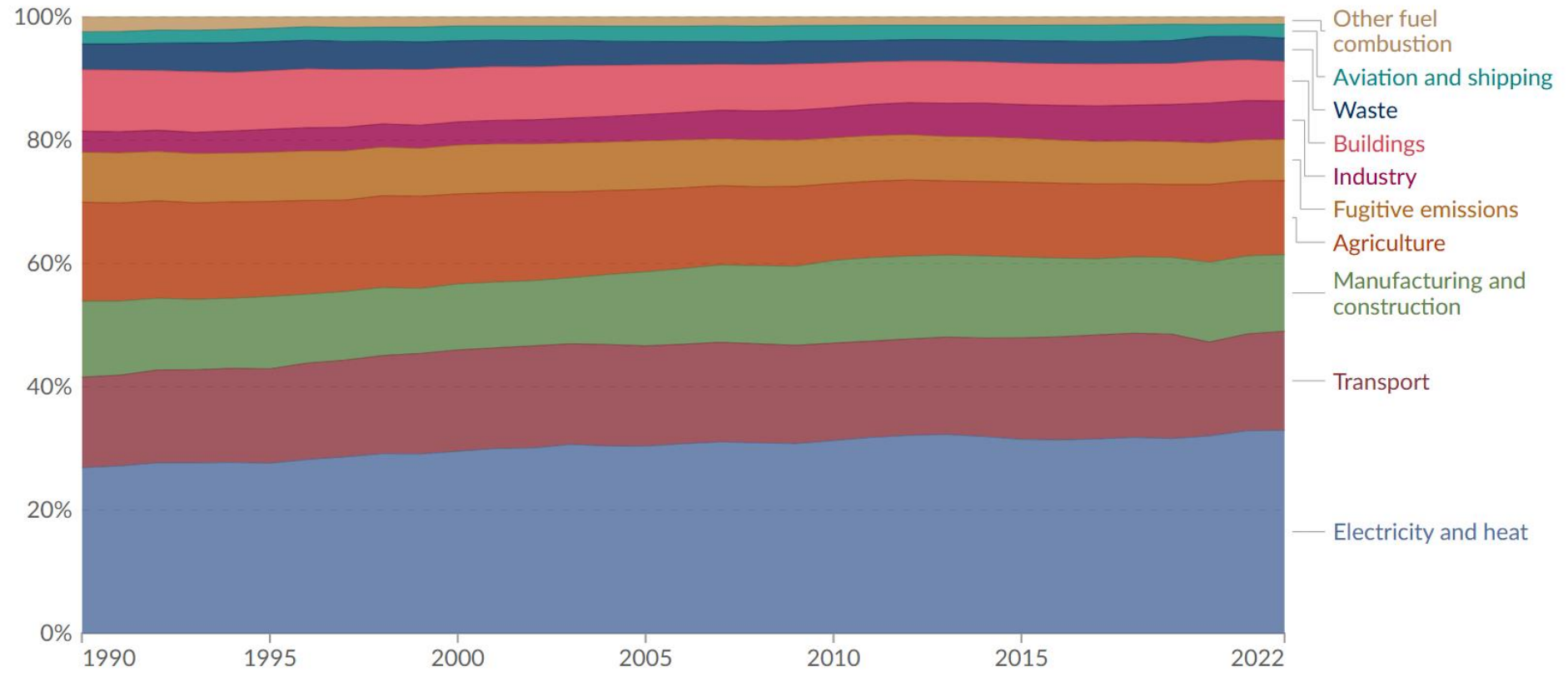


Table Chart

Change country or region

Settings



1990 2022

Data source: Climate Watch (2025) - [Learn more about this data](#)
OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

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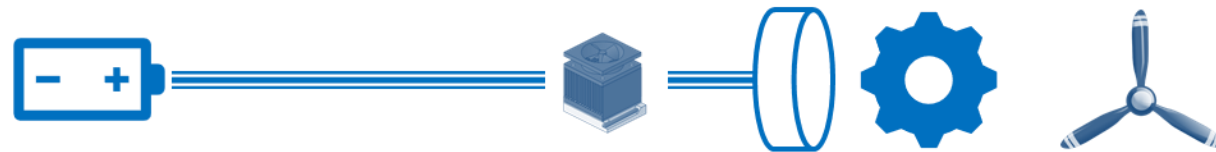


PROPUSLION TECHNOLOGIES

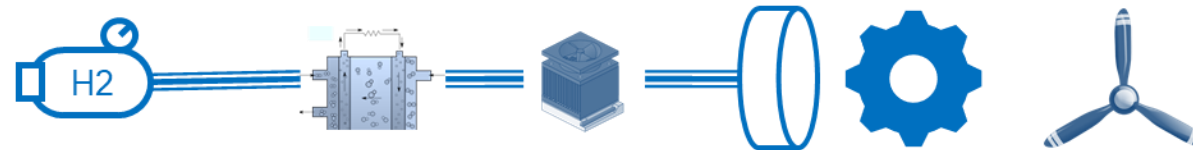


PROPULSION PRINCIPLES

Batteridrivnen



Bränslecell



SAF



Direktförbränning vätgas

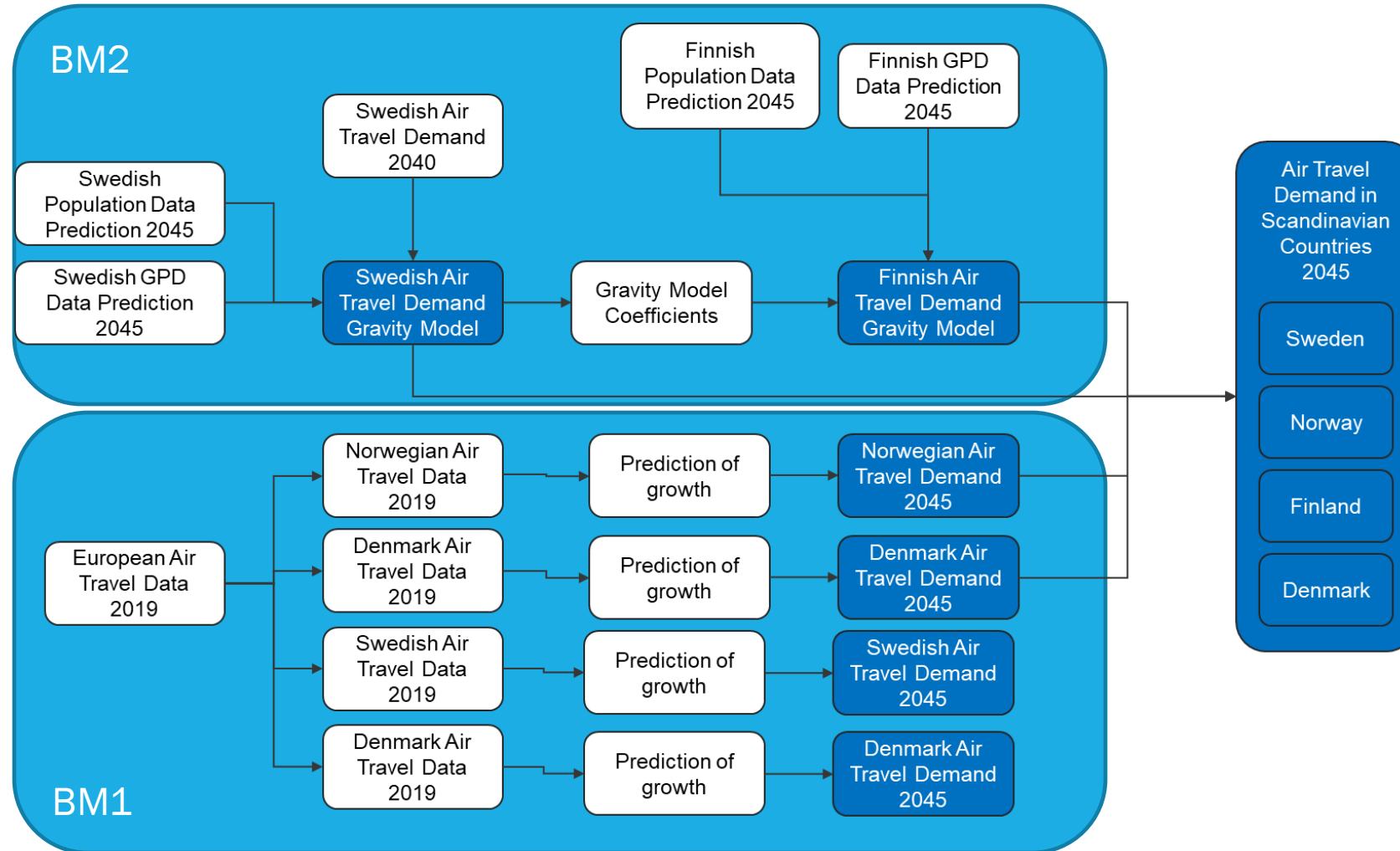




DEMAND MODELS



DEMAND MODELLING APPROACH





AIRCRAFT MODEL AND ASSUMPTIONS

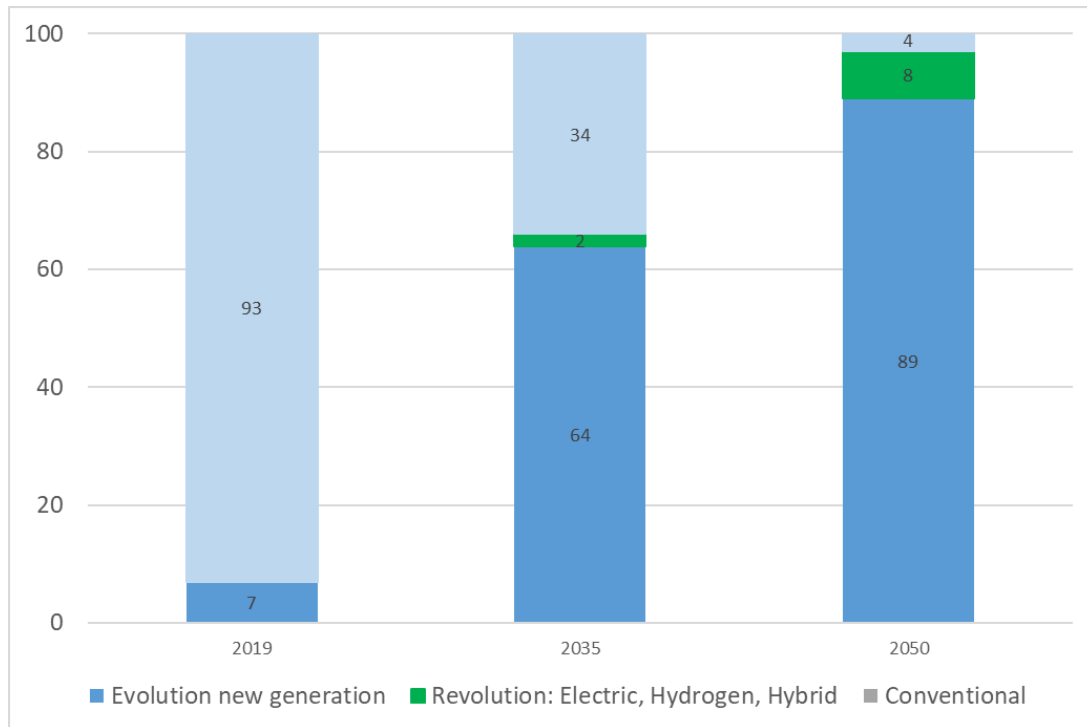


HISTORICAL DEVELOPMENT OF AIRCRAFT



- Average development times of 5-7 based on known technology and known certification rules

FLEET RENEWAL ASSUMPTIONS

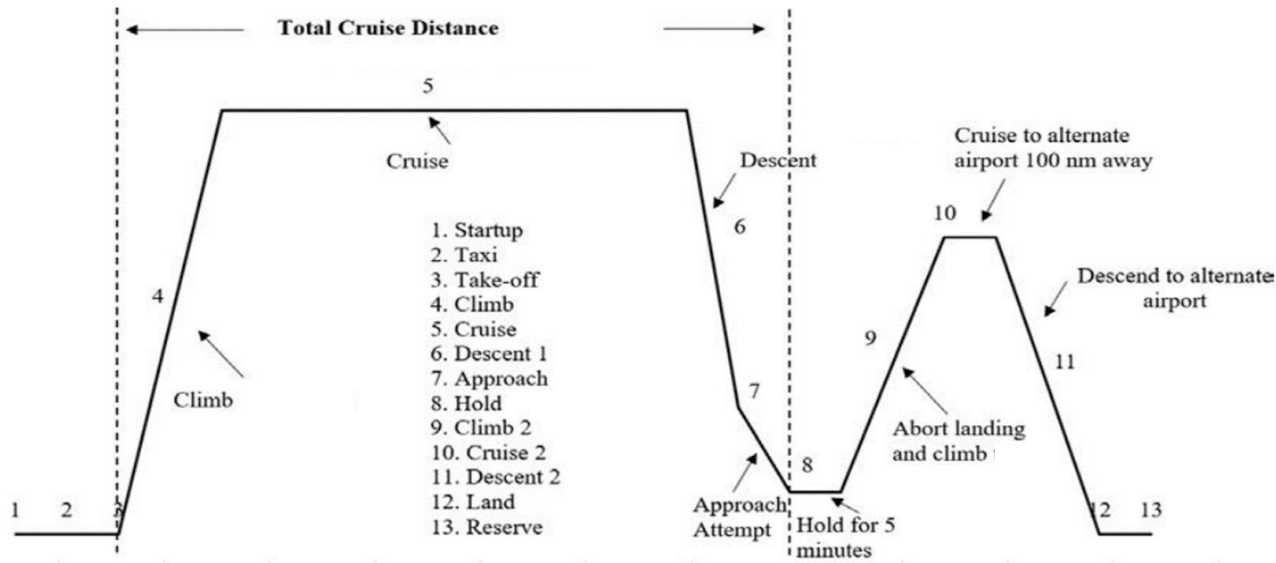


- Notional replacement of aircraft

		Production rate/Month	Introuction year	NB produced	Available in Sweden	NB produced	Available in Sweden	NB produced	Available in Sweden
Seat	Type			2030	2030	2035	2035	2045	2045
9	Battery	2	2028	48	5	168	16	408	30
19	Battery	2	2031			96	10	336	25
34	Hybrid	2	2032			72	7	312	25
49	Hybrid	2	2035			0		240	20
76	Hybrid	3	2035			0		360	28
150	H2	20	2035			0		2400	35

POSSIBLE PRODUCTION RATE

MISSION MODELLING AND ASSUMPTIONS



CS-23 & FAR 23 certifications rules

- 9 & 19 passengers

CS-25 & FAR 25 certifications rules

- 34 & 50 passengers
- 76 passengers (maxweight 86 000 lb (scope clause))
- 90 passengers
- 120 och 150 passengers

Notional mission profile

Flight reserve are always depend on flight operation: here 100NM has been chosen

ASSUMPTIONS

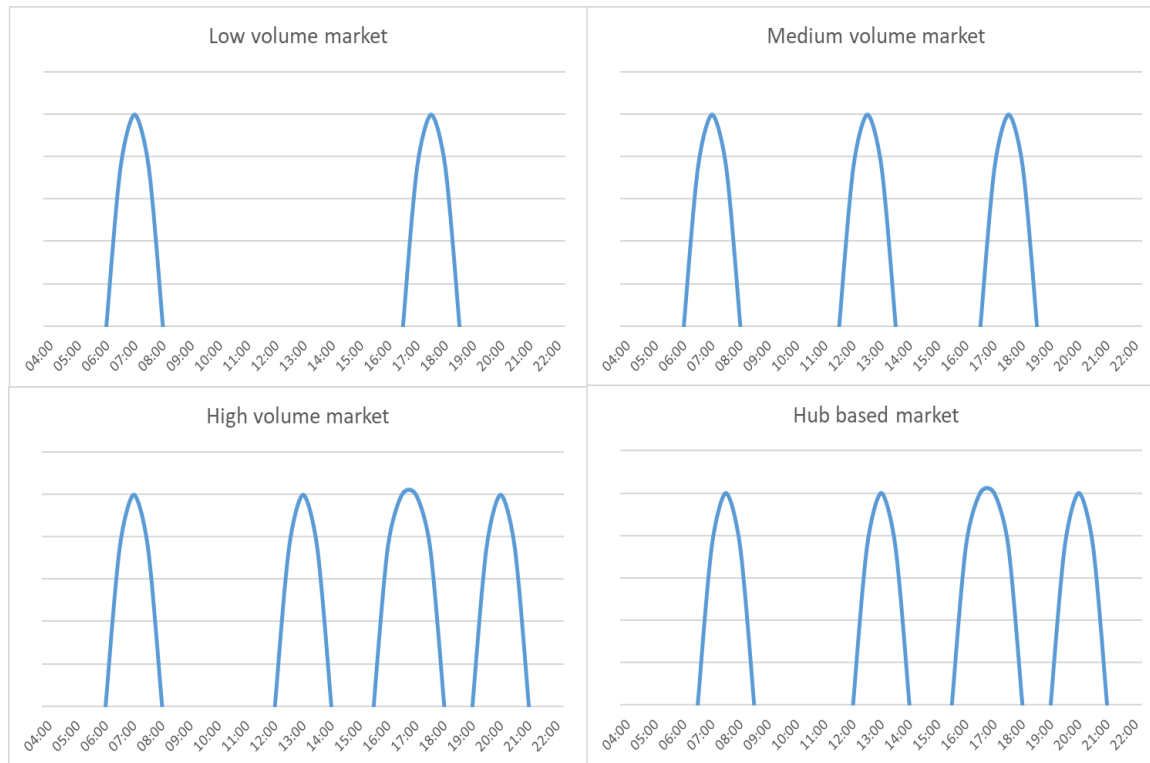
- Electric motor:
 - Efficiency 98%,
 - Power density 5 kW/kg
- Photoelectrochemical cell:
 - Efficiency 98%
 - Power density 2.2 kW/kg
- Cable efficiency 99%
- Power density of fuel cells 1.5 kW/kg
- Power density of cooling systems 2 kW/kg.
- Batterie installed 440Wh/kg (~630 Wh/kg at Cell level)



AIRCRAFT ROUTE ALLOCATION



BASED ON A DAILY REPARTITIONS



- All flights may only use range that maintains reserves
- A maximum of 16 return flights per day is imposed (three two-hour times per day with departures every 30 minutes)
- Establish a baseline of 100% SAF operated aircraft and minimize the number of trips on each route and allocate the largest aircraft that ensures a cabin factor greater than 65%
- Allocate battery-electric aircraft instead of SAF-powered aircraft on as many routes as possible, with range as the limiting factor.
- On the routes still served by SAF aircraft, allocate hydrogen fuel cell aircraft with regard to range.
- On the routes still served by SAF aircraft, reallocate direct combustion hydrogen aircraft..

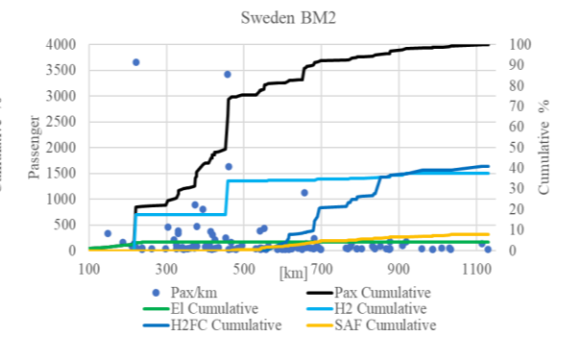
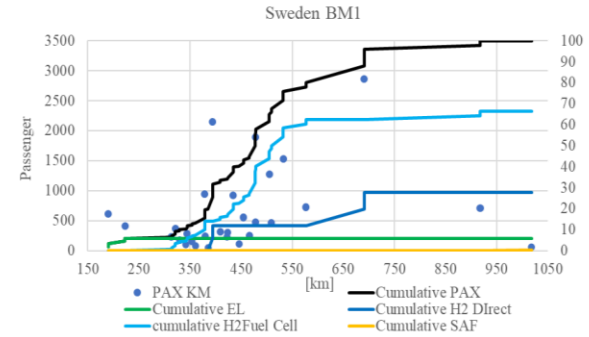
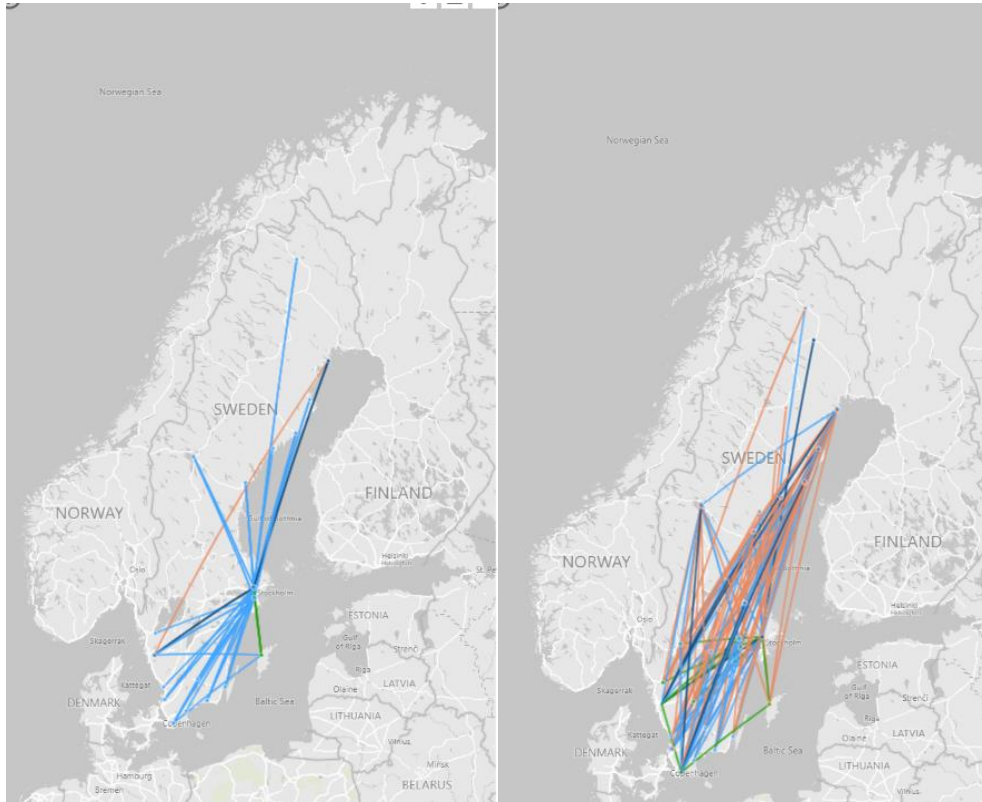


RESULTS



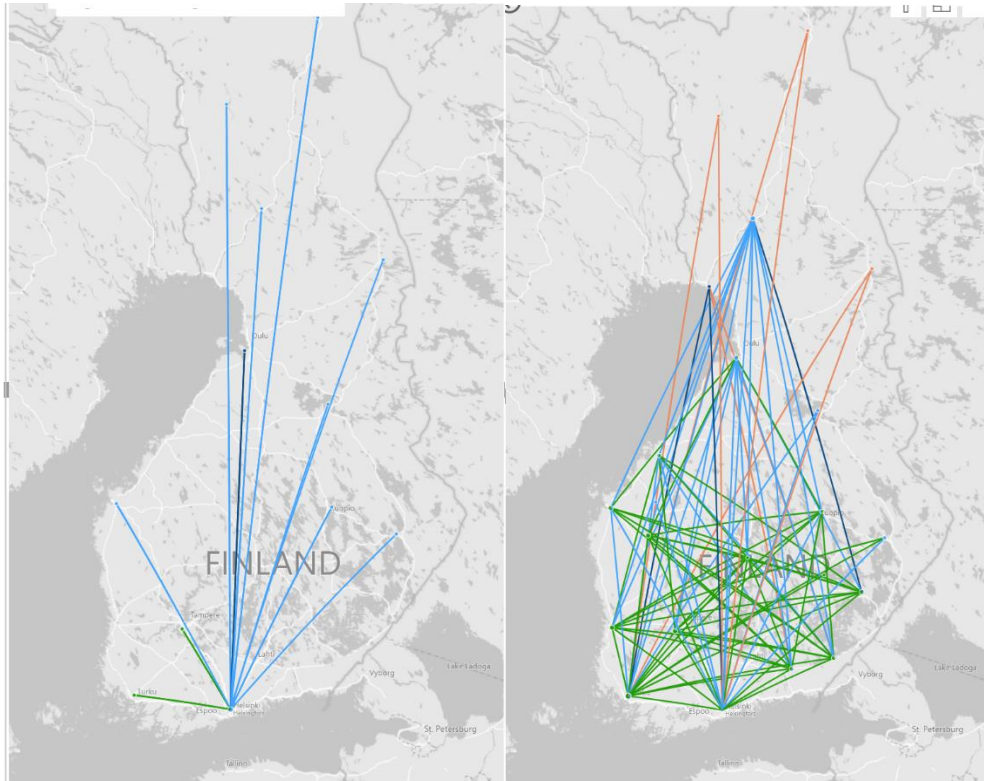
	Sweden		Finland		Norway	
	Daily Pax Demand	Nr. of Flights	Daily Pax Demand	Nr. of Flights	Daily Pax Demand	Nr. of Flights
On all routes	9541.6	820	15778	351	89938	101
On routes with more than 24.6 pax/day	7699.7	46	14401	101	89938	101
On routes over 150 km	7699.7	46	13636	87	n/a	n/a

SWEDEN SCENARIO 3



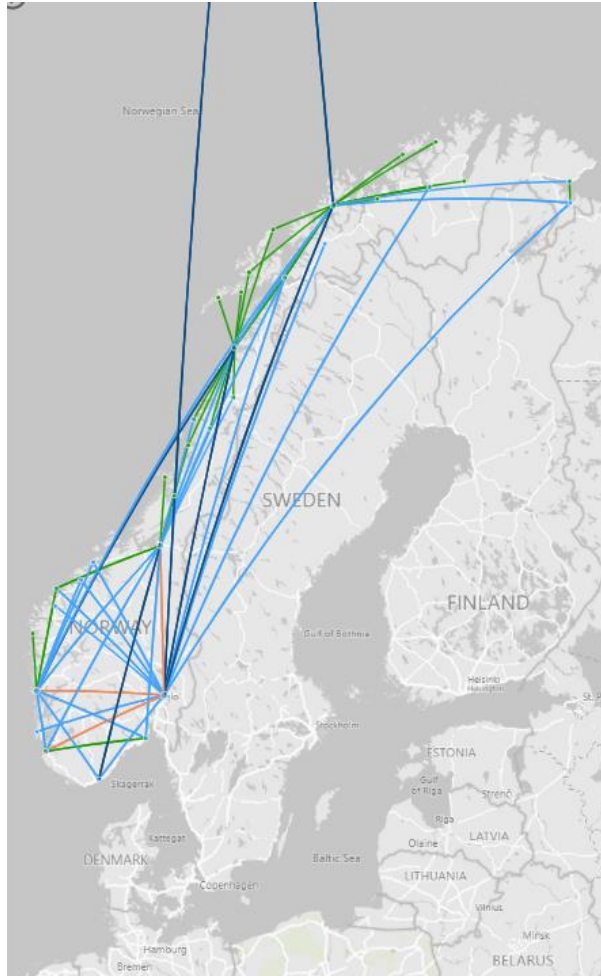
Daily Flight BM1						Daily flight BM2					
PAX	EL	H2	H2FC	SAF	Total	Pax	EL	H2	H2FC	SAF	Total
9				8	8	9	4		40	94	138
19			6		6	19	8		24	30	62
34	68		26		94	34	24		20	20	64
76			344		344	50		10			10
150		72			72	76			146		146
Total	68	72	376	8	524	120		4			4
						150		50			50
						Total	36	64	230	144	474

FINLAND SCENARIO 3



	BM1				BM2					
Pax	EL	H2	H2FC	Total	PAX	EL	H2	H2FC	SAF	Total
34	34			34	9	50		6	12	68
76			116	116	19	42		4	6	52
150		36		36	34	140		24	4	168
Total	34	36	116	186	50		6			6
					76			128		128
					Total	232	6	162	22	422

NORWAY SCENARIO 3

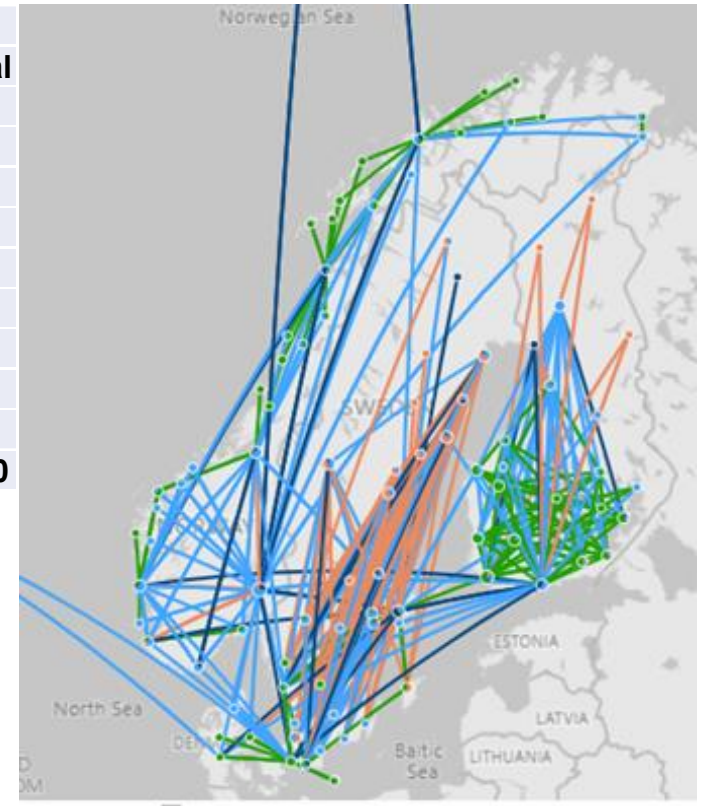


PAX	EL	H2	H2FC	SAF	Total
19	46				46
34	150		20		170
50		2			2
76			442		442
90		10			10
120		6			6
150		78			78
220				152	152
Total	196	96	462	152	906

SUMMARY DAILY FLIGHT IN SCANDINAVIA SCENARIO 3



Pax	BM1					Pax	BM2				
	EL	H2	H2FC	SAF	Total		EL	H2	H2FC	SAF	Total
9				8	8	9	64		46	106	216
19	46		18		64	19	86		34	36	156
34	414		58	2	474	34	456		74	26	556
50		4			4	50		20			20
76			1144		1144	76			892		892
90		4			4	90		8			8
120		16			16	120		14			14
150		442			442	150		206			206
220				152	152	220				162	162
Total	460	466	1220	162	2308	Total	606	248	1046	330	2230





HUB-SPOKE EXTRA SCENARIO

- Based on demand model 2
- All long route on low volume pax < 34 to be re-allocate to hub
- Find nearest hub to low volume destination airport
- Re-allocate traffic to hub and then hub-hub or hub destination
- Hub based on possibility to accommodate EL or H2FC aircraft

NETWORK RESULTS

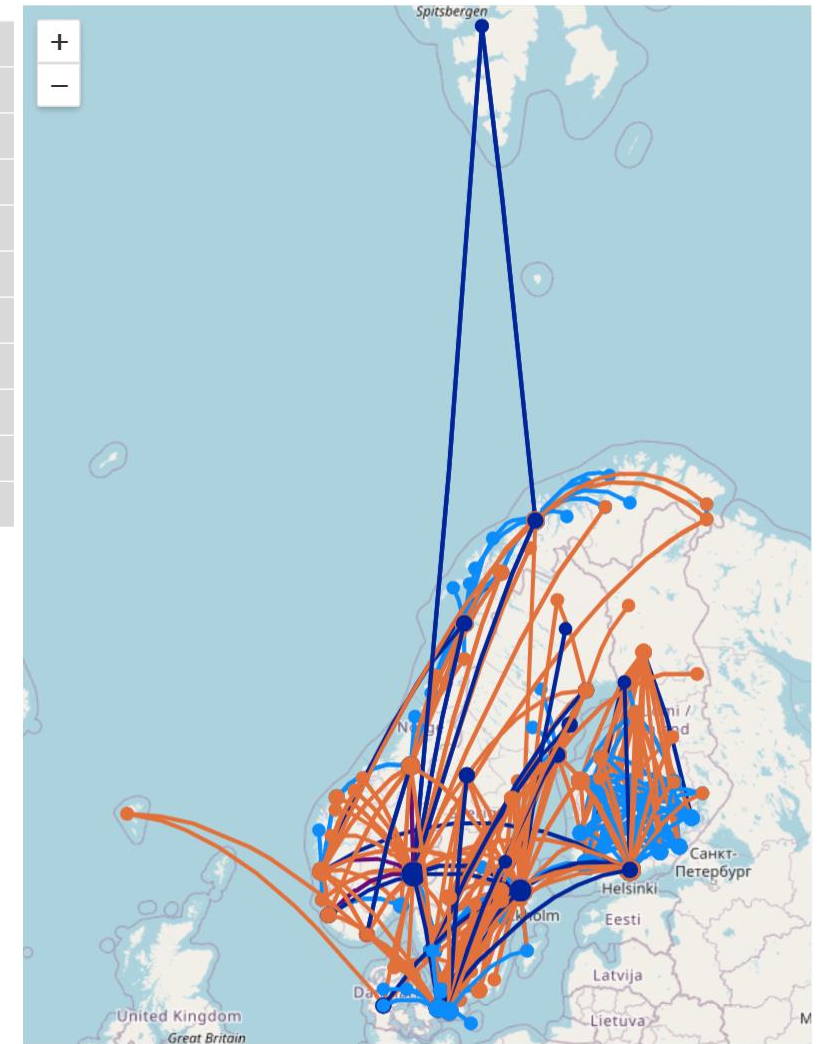
Tech ● EL ● H2 ● H2FC



	Norden				
Pax	EL	H2	H2FC	SAF	Total
9	128		54		182
19	128		94		222
34	490		114		604
50		22			22
76			1018		1018
90		10			10
120		14			14
150		314			314
220				134	134
Total	746	360	1280	134	2520

	Sweden			
PAX	EL	H2	H2FC	Total
9	22		44	66
19	46		46	92
34	44		50	94
50		10		10
76			164	164
120		4		4
150		52		52
Total	112	66	304	482

Tech ● EL ● H2 ● H2FC ● SAF



SOME KEY TAKE AWAY

- Battery-powered aircraft are strongly dependent on battery development and primarily on energy density (Wh/kg)
- Hydrogen is dependent on the development of technology and hydrogen production
- Hydrogen production and distribution is key to the future of hydrogen-powered aircraft and is a huge challenge...
- SAF is considered a necessity to contribute to more environmentally friendly air transport
- There is no single technology that solves all the problems on its own
- The development of new aircraft based on known technology and available certification base takes on average 5 to 7 years. Therefore, the aircraft to be put into service in 2030 will be based on technologies that are known today
- The replacement of all aircraft takes many years. Therefore, the aircraft fleet in 2045 will be based on technology that was available long before 2045
- The replacement of aircraft cannot be carried out faster than the production capacity and necessary infrastructure development that can be achieved
- Certification rules for the various technologies need to be put in place to ensure that the aircraft developments can be carried out and maintain the same safety standard as today.
- Based on the study, it can be seen that the following aircraft have a larger impact on a conversion:
 - battery-powered aircraft mainly in the 34-passenger class
 - fuel cell aircraft 76 passengers
 - hydrogen aircraft 150 passengers
 - SAF aircraft in the 220 passenger class.



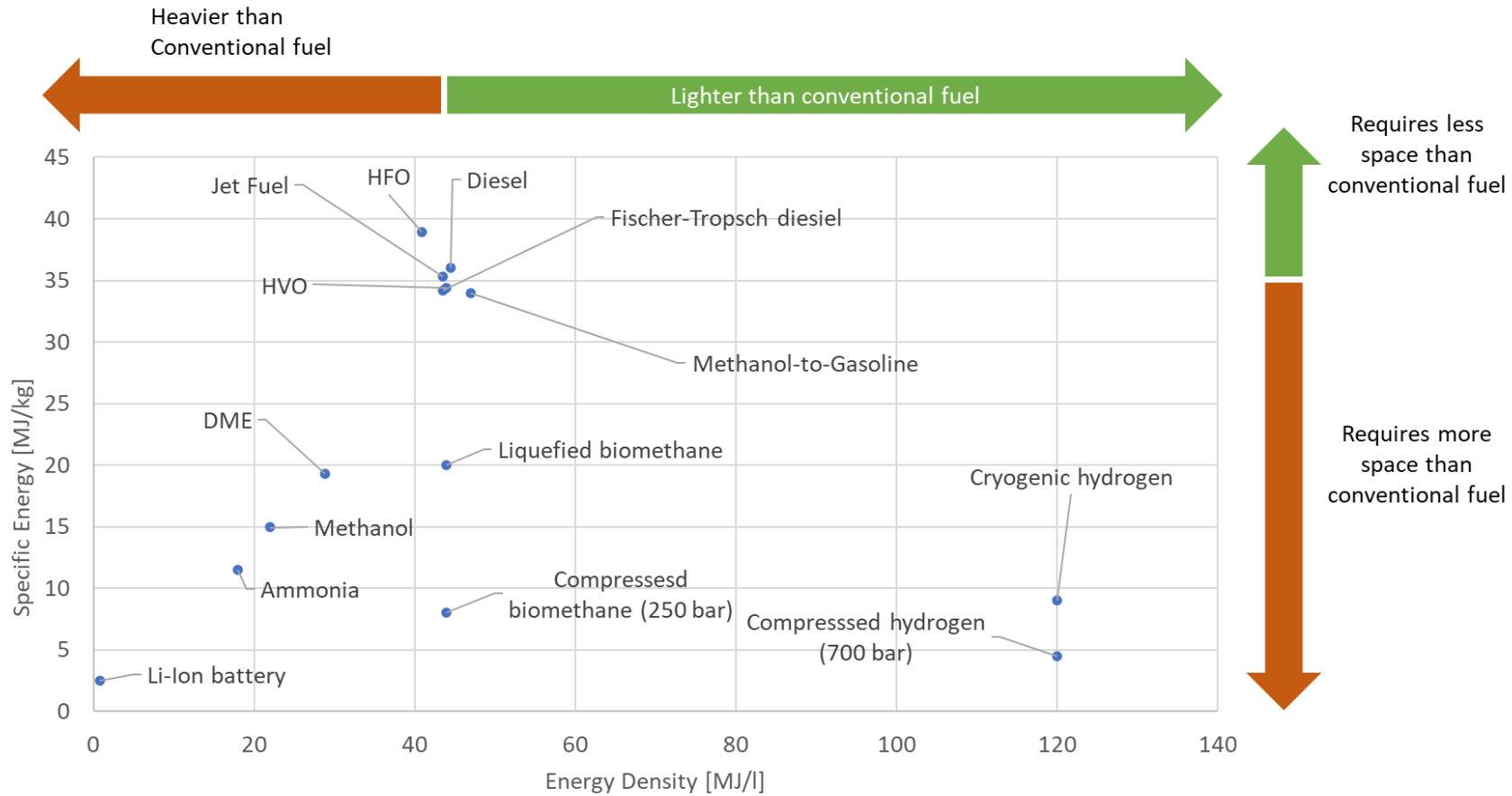
CONCLUSION

- This is fare more aggressive than refuel Europe
- This is optimistic in terms of aircraft certification and production rates
- All development program are showing delays...
- Economics must be included
- Cost modelling is on-going work and will be integrated to network allocation


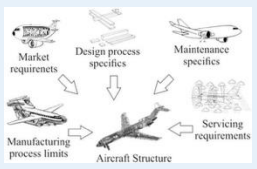


The background features a series of radiating lines in shades of blue, teal, and purple, creating a sense of depth and movement. A prominent black diagonal line runs from the top-left towards the bottom-right. The text 'THE END' is centered in the lower half of the image.

THE END

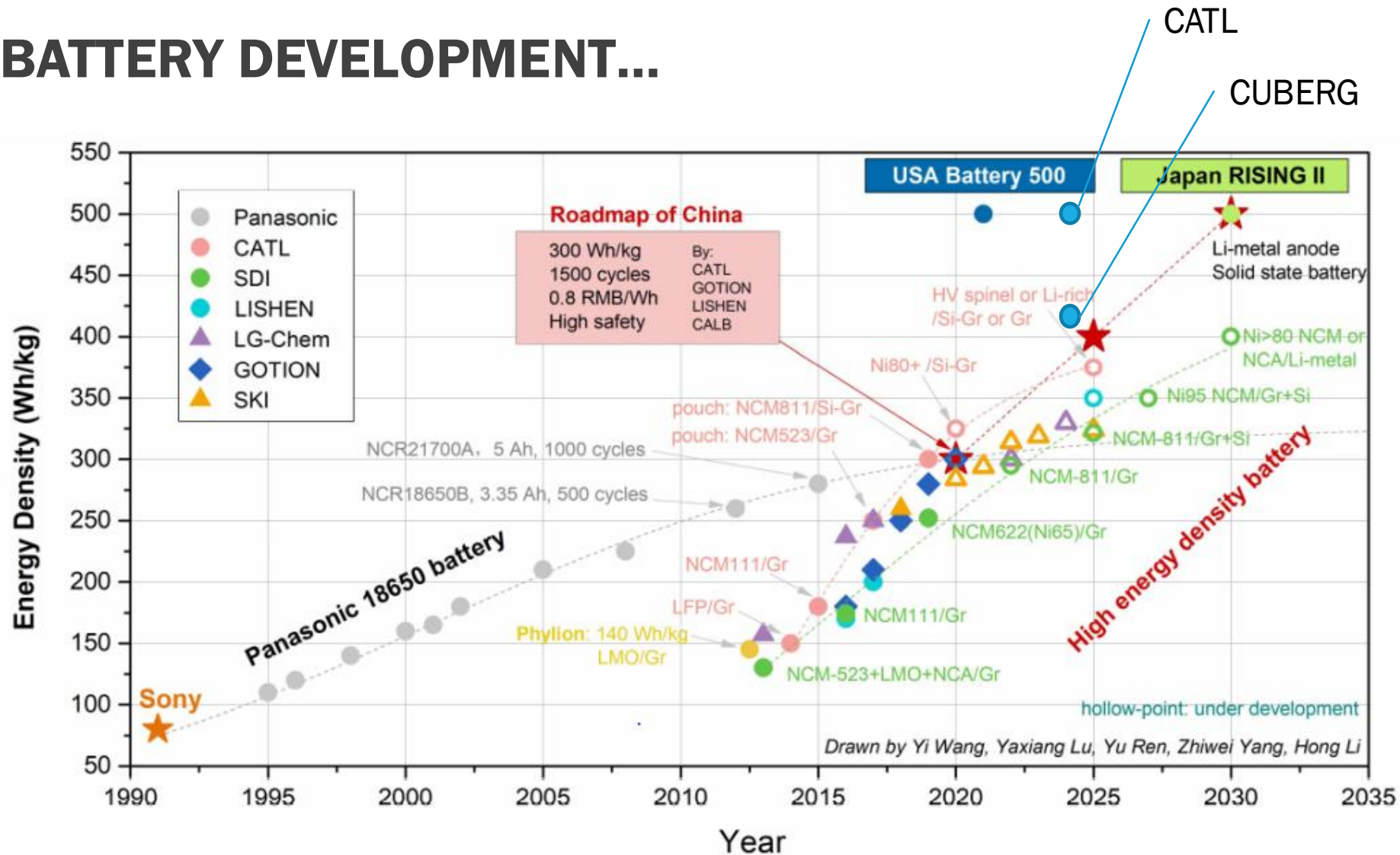
“FUEL” ALTERNATIVE



HYDROGEN VS SAF VS BATTERIES

		H2 fuel cell	H2 turbin	Synfuel	Batteries
	Climate impact	75-90% reduction	50-75% reduction	30-60% reduction	100%
	Aircraft Design	Limited range commuter to short-range	Almost all ranges, hard to reach >10000km	Only minor changes	Limited range Short range
	Aircraft operation	Longer refuelling time	Longer refuelling time	Same turnaround times	Potential same
	Airport infrastructure	LH2 distribution and storage required		No changes	Electrical charging installation

BATTERY DEVELOPMENT...



SOME EQUATION...

Aerodynamic Efficiency

$$R = \left(\frac{\Delta h_{fuel}}{g} \cdot \eta \right) \cdot \frac{L}{D} \cdot \ln \left(\frac{1}{1 - \frac{m_{fuel}}{M_{TOW}}} \right)$$

Engine efficiency

Structure Efficiency

SOME MORE EQUATIONS..

$$R = \left(\frac{\Delta h_{fuel}}{g} \cdot \eta \right) \cdot \frac{L}{D} \cdot \ln \left(\frac{1}{1 - \frac{m_{fuel}}{M_{TOW}}} \right)$$

$$R = \left(\frac{E_{battery}}{g} \cdot \eta \right) \cdot \frac{L}{D} \cdot \frac{m_{battery}}{M_{TOW}}$$

$$1 = \frac{m_{empty}}{M_{TOW}} + \frac{m_{payload}}{M_{TOW}} + \frac{m_{fuel \text{ or } battery}}{M_{TOW}}$$