Hydrogen Aviation regional

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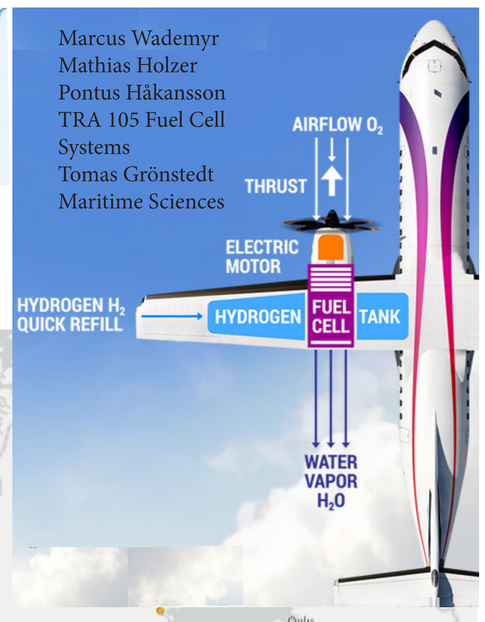
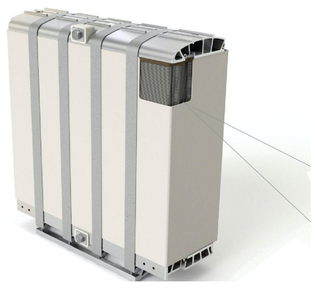
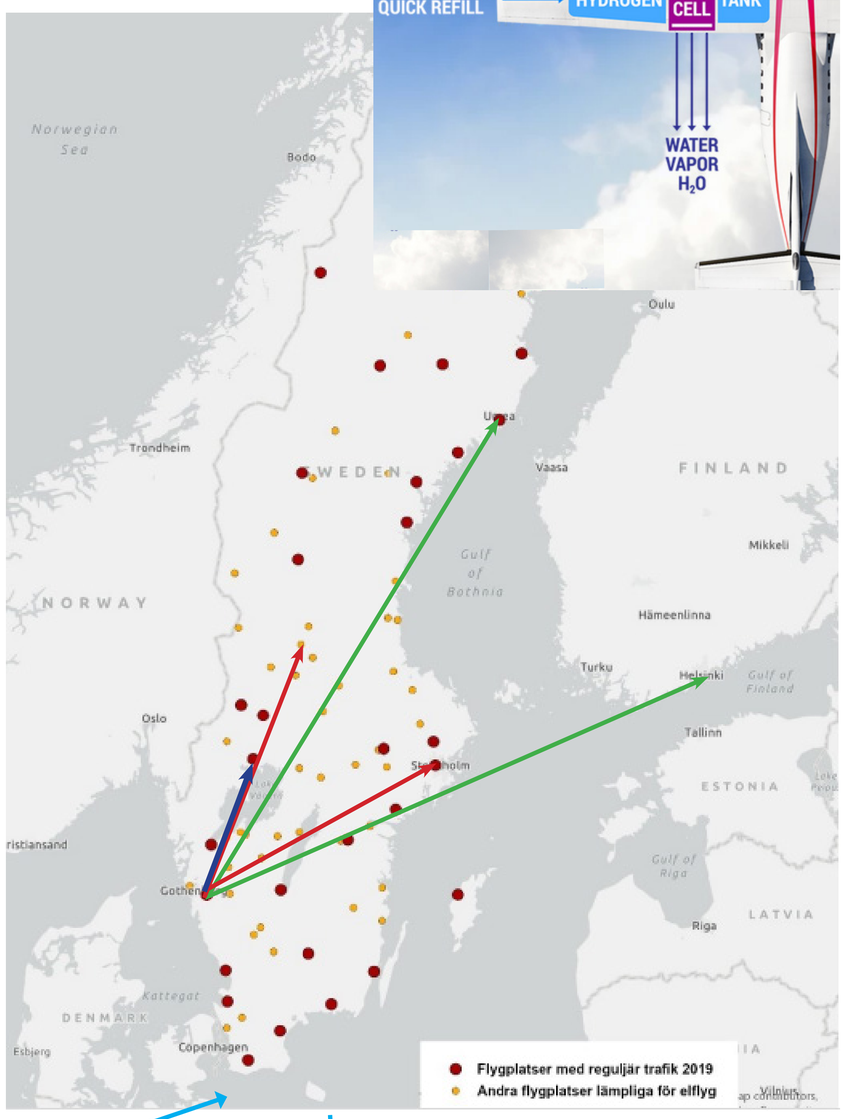
Today, aviation is responsible for 2% of the global CO2 emissions, as it is still primarily based on fossil fuels. Alternative fuels, such as hydrogen (H2), are proposed to accomplish the zero-emission target by 2050. In this project the use of fuel cell systems (FCS) in a small aircraft for 19 passengers is investigated. The H2 for the fuel cells is considered to be sustainably produced by eletrolysis. All assumptions are based on a maximum take off weight of 8.218 kg, including a maximum weight of 2.400 kg for all hydrogen-related systems (incl. fuel).

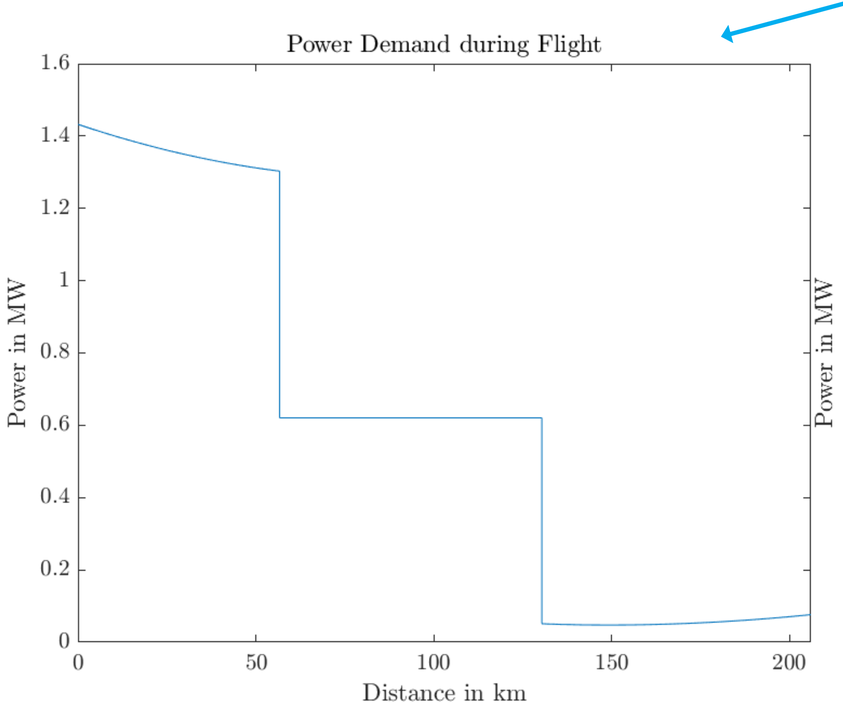


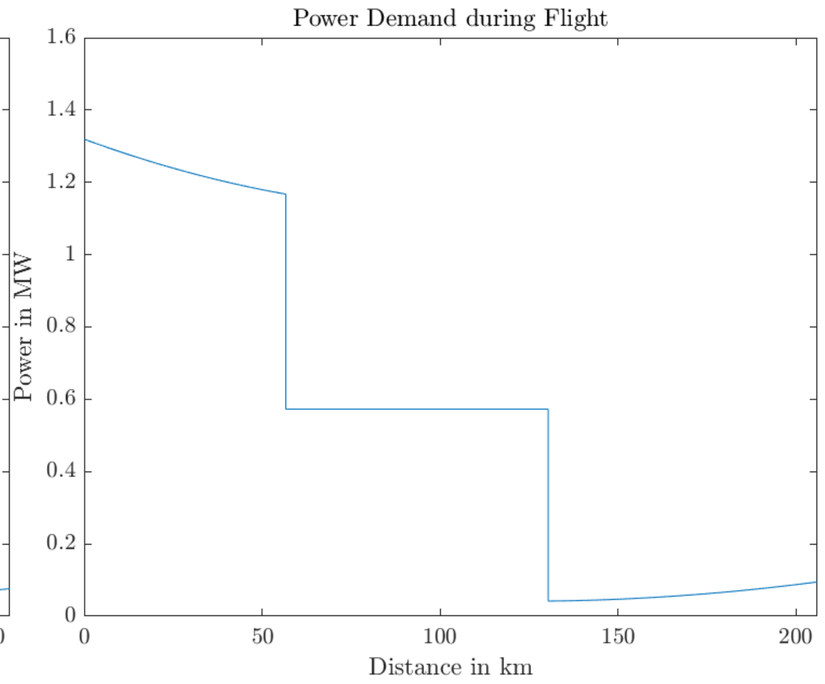


Fuel cell stacks of 100kW output are stacked depending on the energy demand

Hydrogen tanks with 700 bars compressed hydrogen







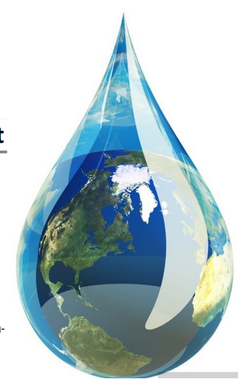
Distances for different cases: Unlike battery electric propulsion, where power output and travel distance scale u, the range for a hydrogen powered aircraft with a defined power output can vary significantly depending on the tank capacity. Thus, five different cases are compared and shown in figures to the right. For available fuel cell systems ranges up to 800 km can be achieved in comparison to a 2030 battery system of equivalent weight. When projecting the technological development of fuel cells to 2030 too, distances of 1.500 km become feasible - mainly due to increased efficiencies. A major drawback of the fuel cell systems will be the necessary storage space, both for the tanks and the fuel cells. While FCs for the desired power output will need about 3 m³ of space, the tank size varies with the demanded range. Therefore, the dimensions of the aircraft have to be optimized to fit the fuel cell system.

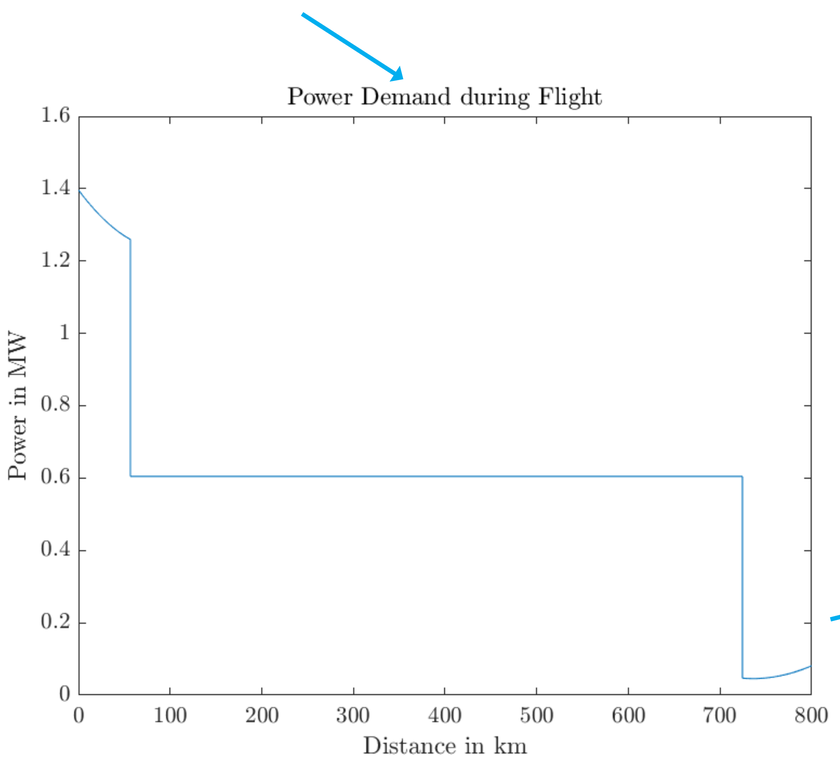
Efficiencies	Value	Future Value
Propeller	87%	87%
Motor	90%	90%
Controller	98%	98%
Fuel cell (cruise, decent)	60%	65%
Fuel cell (climb)	45%	50%

Gravimetric density	Value	Unit
Fuel cell Now	1,6	kW/kg
Fuel cell Future	8	kW/kg
Electric motor Now	5,2	kW/kg
Electric motor Future	10	kW/kg
Storage tank Now	12,3	kgtank/kgH2
Storage tank Future	9	kgtank/kgH2

Case	Volume(700bar)	Volume (Liquid Hydrogen)	Unit
1	0,51	0,3	m3
2	0,92	0,54	m3
3	1,8	1,1	m3
4	0,43	0,26	m3
5	2,9	1,72	m3

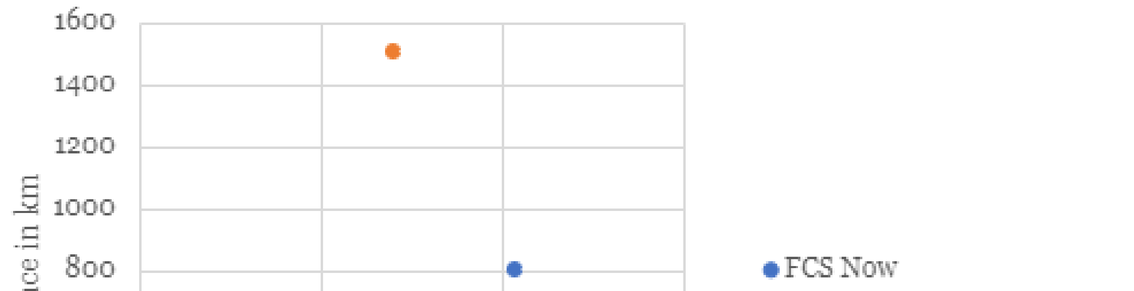
The volume presented in the table above are only referring to the volume created by the compressed or liquified hydrogen, more space will be needed due to the size of the storage tanks.





Battery + Fuel Cell: In the left hand figure the power demand for a flight distance of 800 km is plotted.
For climbing (first 50 km) the power demand is much higher than during cruise and descent, which results in an overdimensioned FCS for the majority of the flight time. By implementing a hybrid battery+supercap+ fuel cell system, where the batteries are designed to provide power only during climbing, weight can be minimized drastically - or range can be further increased.

Case	Distance	Unit
1	206	km
2	400	km
3	800	km
4 (future)	206	km
5 (future)	1500	km
6 (comparison electric)	206	km



To destination

Conclusions

- While weight is not a problem for H2 aviation, the volume of FC units and H2 storage is, since the FC stacks need 3 m3 and the tanks need at least 0,5 m3 (depending on travel distance).
- The max. power output of the FCs is constant in regard of different travel distances.
- Further investigation is needed on heat exchanging since excess heat will be produced during the FC operation. Since the max. load was 2.400 kg and for all proposed cases it is below 2.000 kg it fits. But again, there will be a storage space issue.
- Values for future FC efficiencies and gravimetric energy densities are only assumptions and might deviate significantly.
- Positioning of the FCs and H2 tanks has to be examined in more detail.

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