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Transition scenarios for climate-neutral flight

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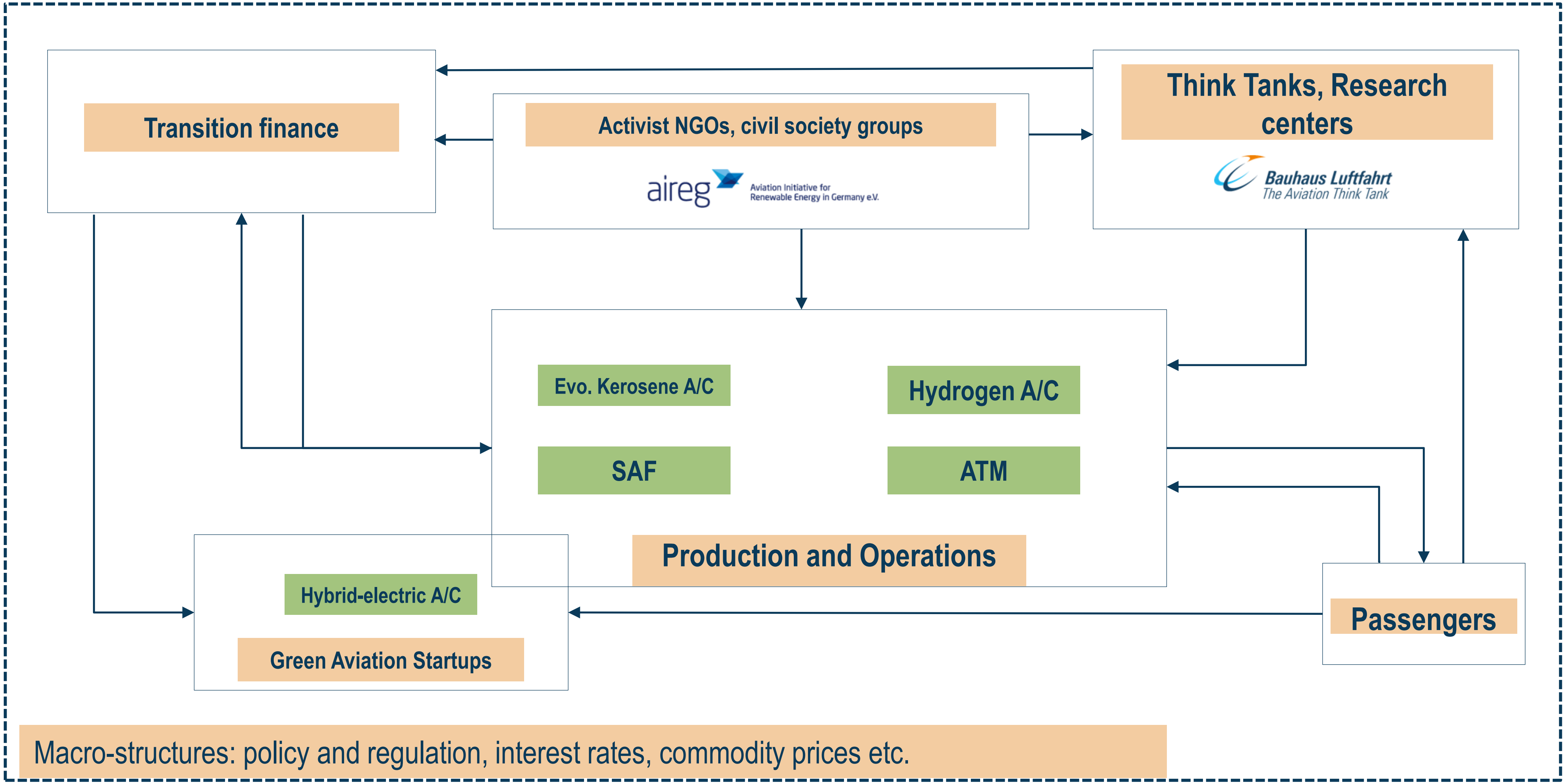
Transition to climate-neutral flight

- **The BHL approach to analyse aviation's transition**

- **The BHL Airline Decarbonisation Model**

- **Capabilities of the model**
  - Results from ReFuelEU scenario projection

The BHL approach – the Aviation Sector as a system



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The BHL Airline Decarbonisation Model

Objective

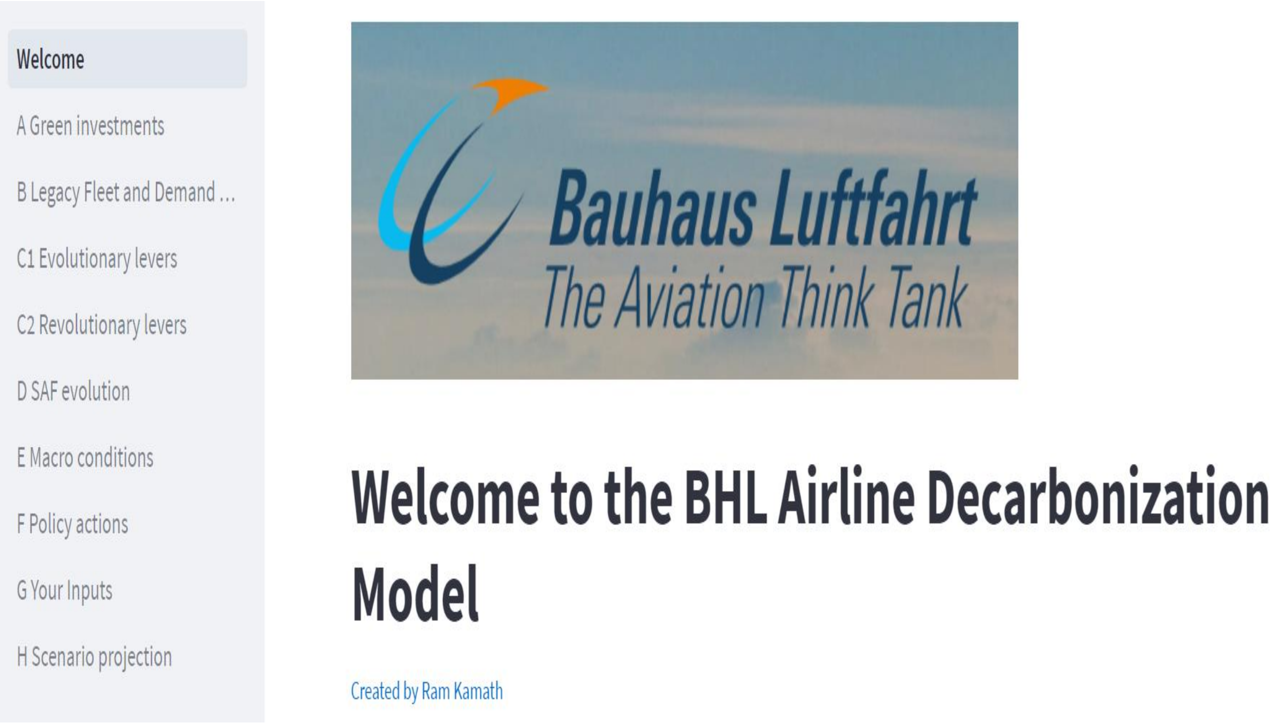
- To explore possible transition-scenarios for the aviation system (from the airline perspective)
- Scenarios are described through the evolution of various metrics

Systemic transition

- Inputs from various stakeholders - aeronautical engineers, chemists, economists, green-finance bankers etc.

A web-app

- Planned to be available for access through the BHL website



The Airline Decarbonisation Model

Capabilities

- Project transition scenarios from 2020 to 2075, for an airline with aircraft for the short-haul, medium-haul, and long-haul market segments

Fleet

- Fleet strength and fleet composition evolution
- RPK evolution

Decarbonisation

- Carbon emissions
- Carbon emissions / RPK
- Role of different decarbonising levers

DOC evolution

- Annual DOC components and shares
- DOC/RPK

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The Airline Decarbonisation Model

Capabilities

- Design transition pathways by controlling the development of evolutionary and revolutionary technologies, SAF production, different policy-instruments, and macro-conditions

Technological levers

- Year of introduction, cost, efficiency of evolutionary or of Hydrogen aircraft

SAF

- Initial production, supply evolution, price evolution for different types of SAF

Macro-Economic conditions

- Evolution of kerosene prices, hydrogen prices
- Interest rates
- Carbon offsetting cost

The Airline Decarbonisation Model

- **"SAF control panel" – approach for evaluation of default values:**
- **Technologies:**
  - HEFA (Hydroprocessed Esters and Fatty Acids)
  - EtJ (Ethanol-to-Jet)
  - PtL (Power-to-Liquid)
  - BtL (Biomass-to-Liquid)
  - HTL (Hydrothermal Liquefaction)
- **Feedstock:**
  - Vegetable oils, animal fat, used cooking oil
  - Crops (wheat, maize, barley, sugarcane, sugarbeet)
  - Agricultural residues
  - Forestry residues
  - Other residues (waste plastic, MSW, food waste, sewage sludge, manure)
  - DAC; CO_2 point sources (fermentation, bioenergy, cement)

MSW = Municipal Solid Waste

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The Airline Decarbonisation Model

- **“SAF control panel” – approach for evaluation of default values:**
- **29 pathways: Clustering into four groups:**
  - First generation biofuels
  - Second generation biofuels
  - PtL-PS: Power-to-liquid with CO_2 from point source
  - PTL-DAC: Power-to-liquid with CO_2 from Direct Air Capture
- **Key performance indicators:**
  - Feedstock availability
  - Jet fuel production cost
  - Global Warming Potential

The Airline Decarbonisation Model

- "SAF control panel"
- How to come up with reasonable default values?
- Feedstock availability on country level
- Flexible process models that account for differences in LCA and TEA on country level
- Weighted average cost and GWP values for each pathway
- Weighted average cost and GWP values for each of the four groups

Example: HEFA with Used Cooking Oil

JF from UCO			
	emissions	potential	cost
Afghanistan	19,46		
Albania	16,05	1,22	1,99
Algeria	26,53	42,01	
Angola	15,96	16,86	1,98
Antigua and B			
Argentina	25,80	148,62	2,00
Armenia	17,88	1,42	1,99
Australia	32,91	27,60	2,23
Austria	17,91	25,41	1,99
Azerbaijan	20,45	14,62	1,98
Bahamas	21,30	0,03	2,26
Bahrain	18,96	1,35	1,97

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The Airline Decarbonisation Model

Before we go to the demos of the RefeuelEU scenario

- We are at the refining stage (e.g. for improving quality of assumptions and inputs) – **results are preliminary**

- We welcome any suggestions, inputs that can help with the refining process
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- The scenario that will be presented are for the European Aviation System

The Airline Decarbonisation Model – ReFuelEU

Refuel-EU SAF Quota scenario

- Greener aircraft are introduced “slowly” (/realistically).
- Investments in evolutionary kerosene aircraft only drop block-kerosene consumption by 10% (eventually peaks at 30% with third generation of aircraft)
- The first hydrogen aircraft is introduced in 2050. Hydrogen aircraft never achieve parity with evolutionary aircraft, with regards to block-energy consumption
- The EU imposes the refuel-EU SAF Quota system. The airlines strictly follow the quotas and sub-quotas (consumption never greater than quota)

The Airline Decarbonisation Model – ReFuelEU

Refuel-EU SAF Quota scenario

	Maximum annual potential [Mt JF]		LCA [Mt CO2e/Mt JF]		TEA [€/kg JF]	
	2020	2075	2020	2075	2020	2075
First generation	43.5	51.4	2.3	1.4	1.0	1.1
Second generation	290.6	290.6	0.9	0.4	0.9	0.9
PtL DAC	566.8	566.8	0.8	0.6	4.6	1.2
PtL PS	252.5	252.5	0.6	0.5	4.1	2.4

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The Airline Decarbonisation Model – ReFuelEU

SAF Quota scenario (Refuel-EU)

Year	Overall SAF quota	1st gen share of quota	2nd gen share of quota (%)	PS-PTL share of quota (%)	DAC-PTL share of quota (%)
2030	6%	65 %	15 %	19 %	1 %
2035	20%	55 %	20 %	21 %	4 %
2040	34 %	45 %	25 %	18 %	12 %
2045	42 %	30 %	30 %	17 %	23 %
2050	70 %	17 %	33 %	16%	34 %
2070	100 %	11 %	29 %	15 %	45 %

Aircraft/Route	Short-haul	Medium-haul	Long-haul
Evolutionary	2038	2048	2058
Hydrogen	2050	2060	2070

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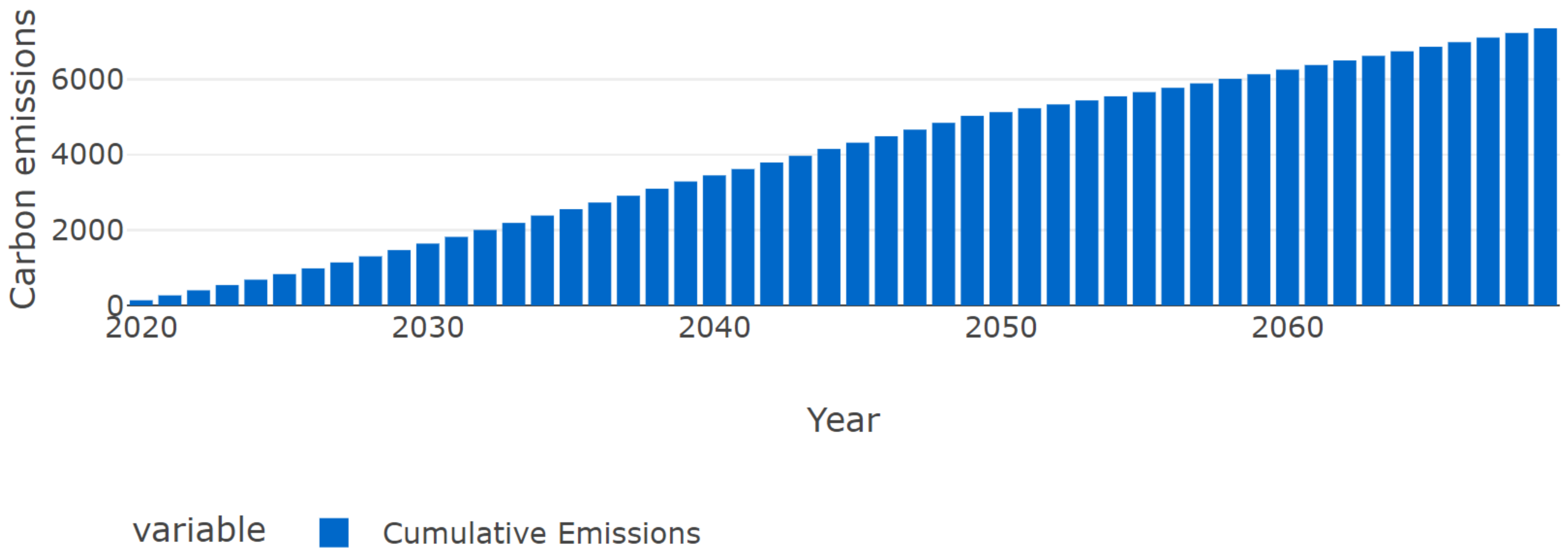
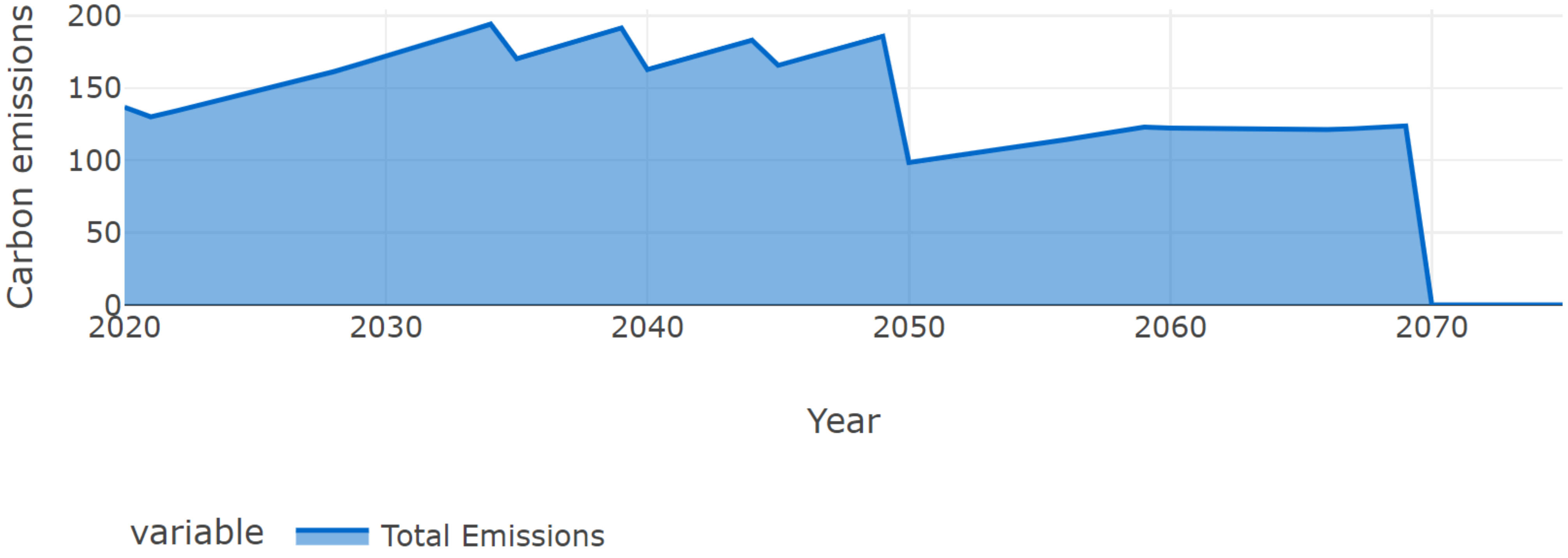
The Airline Decarbonisation Model – ReFuelEU



- **Cumulative carbon emissions**
  - 5129 Mt in 2050
  - 7353 Mt in 2069 (final year of addition)

The Airline Decarbonisation Model – ReFuelEU



Annual carbon emissions

- Peak emissions: 194 Mt in 2034
- 0 carbon from 2070
- 2050 vs 2020 carbon: - 28%

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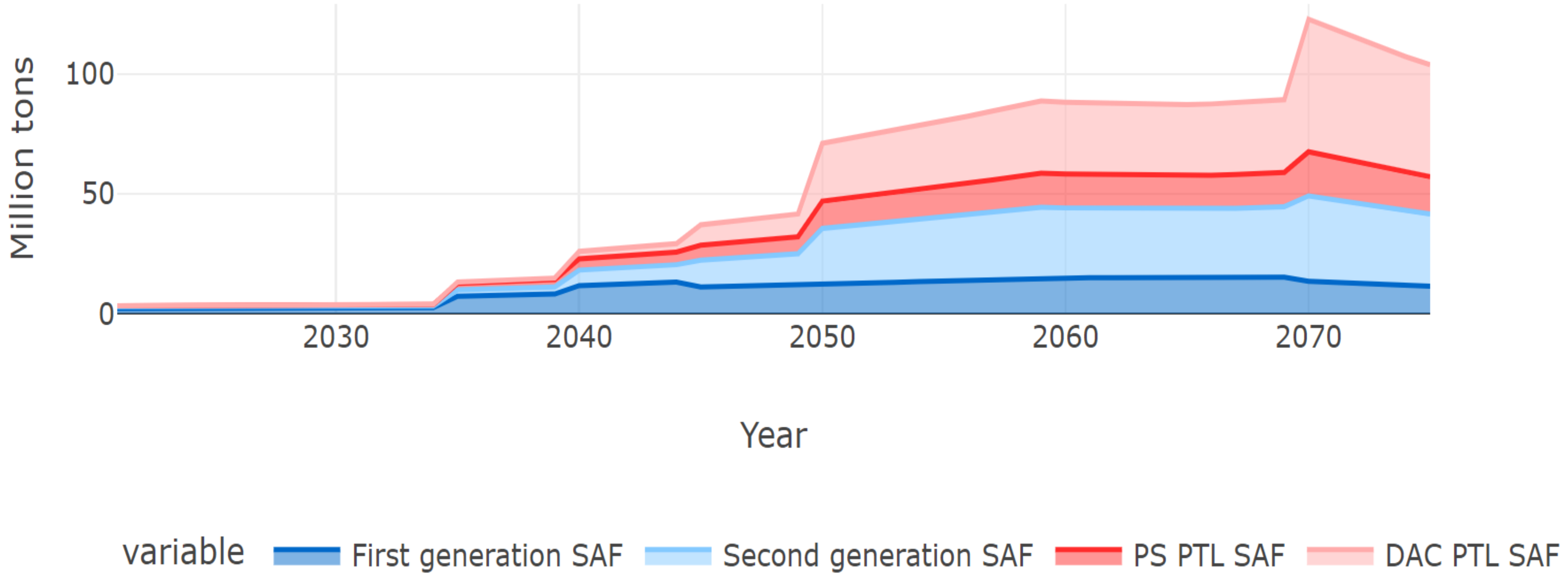
The Airline Decarbonisation Model – ReFuelEU



Annual SAF consumption

- Peak consumption: SAF: 122 Mt in 2070,
- Peak consumption: PTLDAC:55 Mt in 2070, PTLPS:18 Mt in 2075,
- Peak consumption: 2ndgen:35 Mt in 2070,1stgen:15 Mt in 2059

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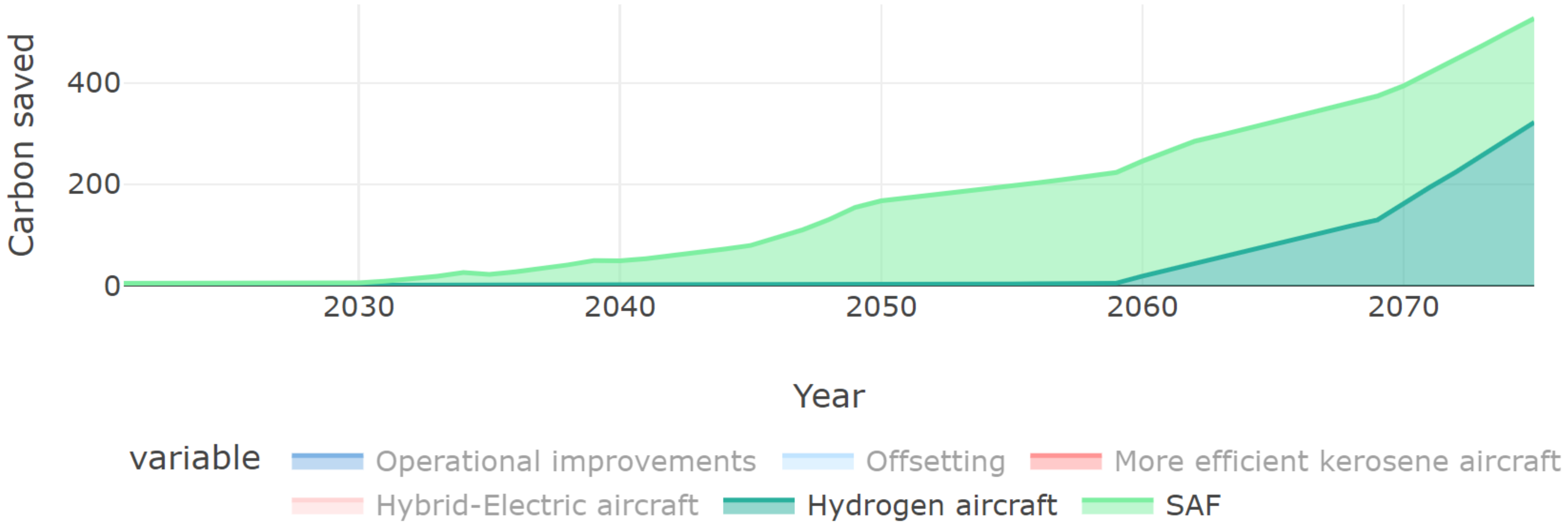
The Airline Decarbonisation Model – ReFuelEU



Emissions saved by SAF vs Hydrogen aircraft

- Cumulative emissions saved - SAF: 6773 Mt vs. LH2: 2232 Mt

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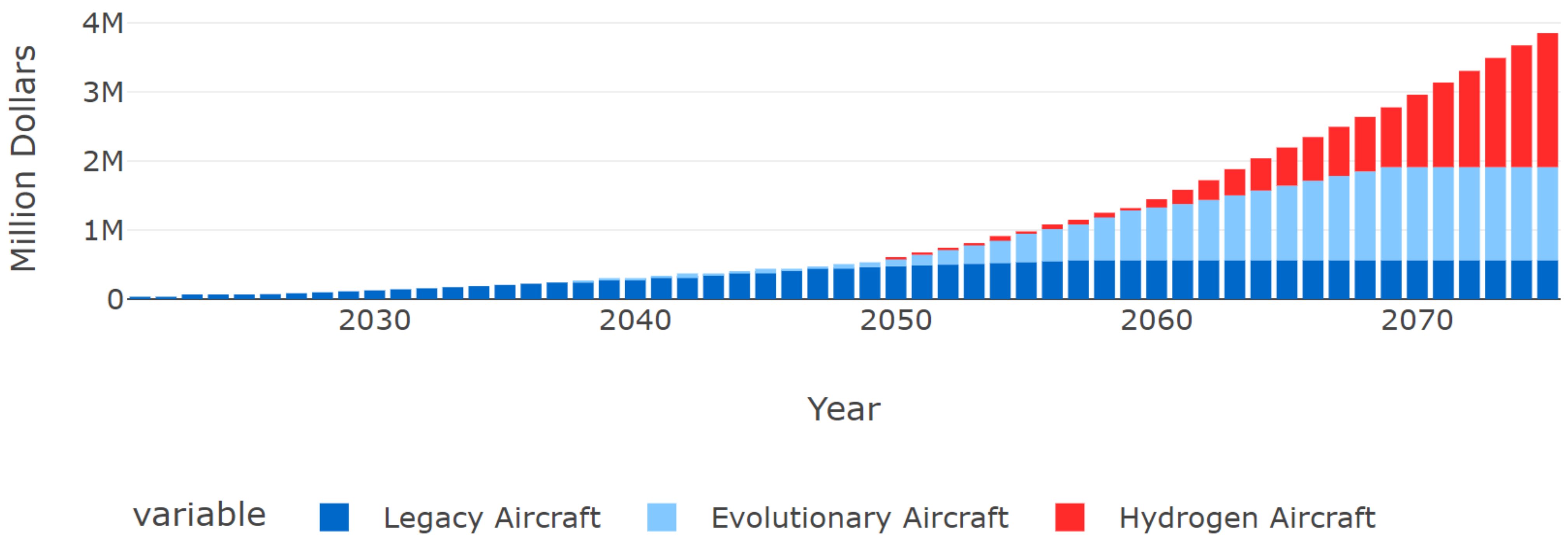
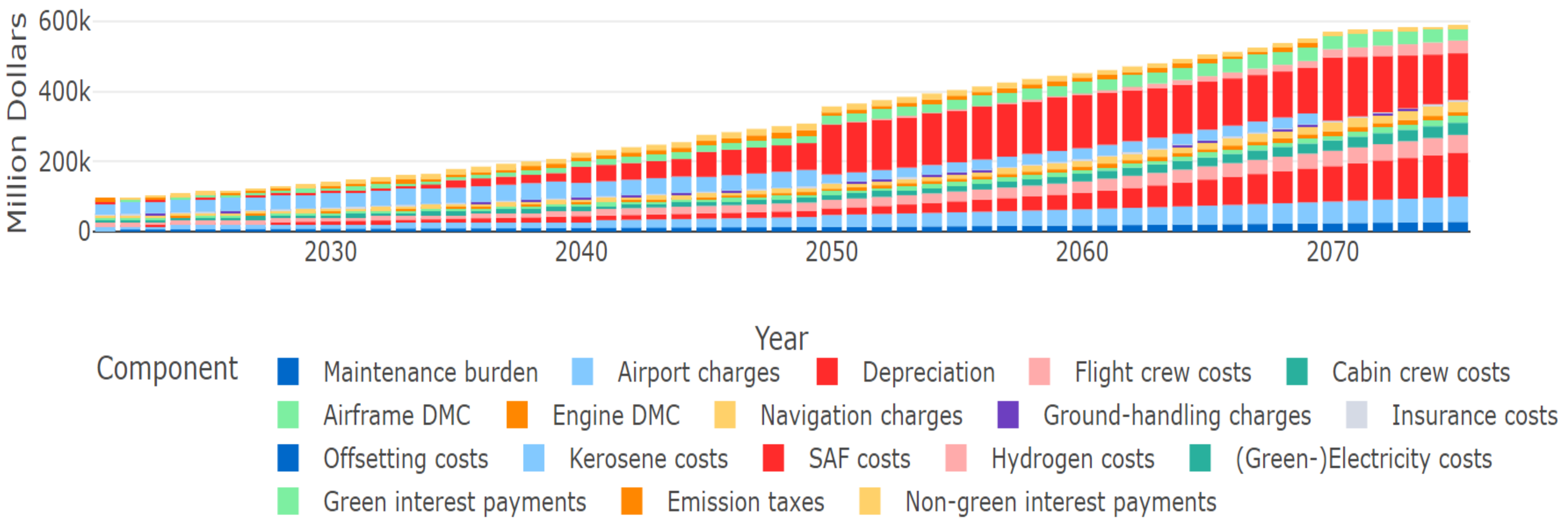
The Airline Decarbonisation Model – ReFuelEU



- **Investments in aircraft (to meet demand growth with 3% CAGR)**
  - Hydrogen: 1940 billion $
  - Evolutionary kerosene: 1348 billion $
  - Legacy kerosene: 562 billion $

The Airline Decarbonisation Model – ReFuelEU



DOC

- SAF expenses: 142 billion $ in 2050 (40% share), peak expense of 180 billion $ in 2070 (32% share)
- DOC of 91 billion $ in 2021 = 0.4 DOC/RPK
- DOC of 357 billion $ in 2050 = 0.06 DOC/RPK
- DOC of 585 billion $ in 2075 = 0.05 DOC/RPK

The Airline Decarbonisation Model – ReFuelEU

Decarbonisation vs DOC+investments

- ReFuelEU leads to decarbonisation of flight by 2070, with cumulative carbon emissions of 7353 Mt
- ReFuelEU requires capex investments of 3.8 trillion $, just for purchasing aircraft
- DOC of 585 billion $ in 2075 = 0.05 DOC/RPK

Comparing scenarios

- We use the model to explore how decarbonisation year, capex investments, and DOC, DOC/RPK compare between different scenarios
- Scenarios presenting Capex challenge vs Opex challenge