Using CAST to simulate sustainable aviation scenarios

The objective of this study is to explore sustainable future scenarios for air transport using the tool CAST (Climate and Aviation - Sustainable Trajectories), shown in Figure 1, which simulates climate trajectories for aviation and assesses their sustainability under the Paris Climate Agreement.

This study will allow you to discover the different challenges of the climate transition for air transport system. It is divided into 4 parts that you will deal with successively:

- Getting started with the tool CAST and analysis of a reference scenario
- Sustainable climate scenarios for CO_2 emissions
- Taking into account non-CO_2 effects in the scenarios
- Towards the concept of environmental problem shifting

You will be asked to write a report per pair in response to this topic, of no more than two pages, in addition to the completed appendix table.

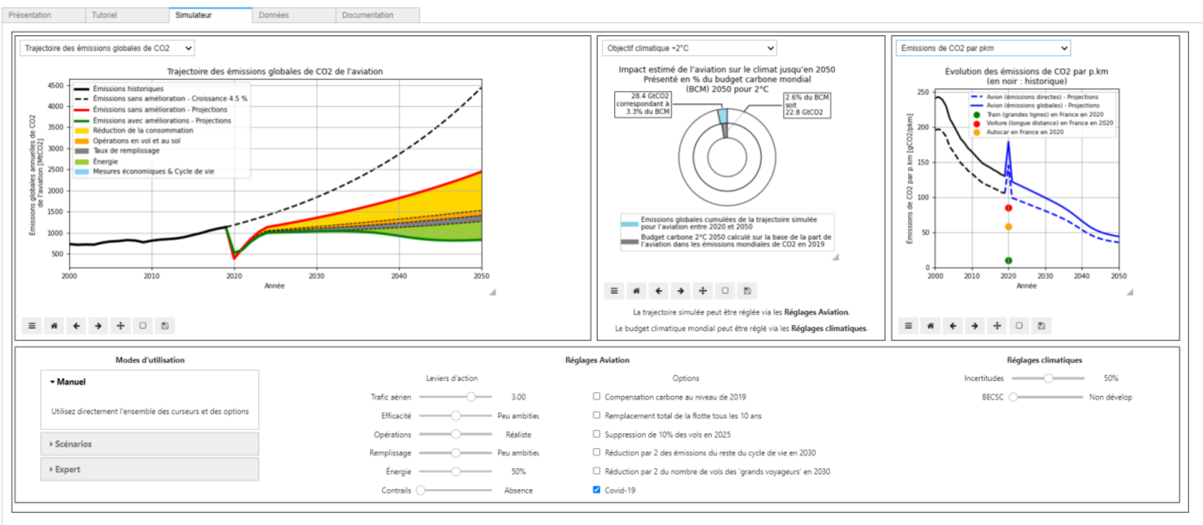

Figure 1 : Overview of CAST interface

1. Getting started with the tool CAST and analysis of a reference scenario

Different modes of use, more or less complex, are available on CAST and will be explored in this part:

- Manual: the user moves sliders to trace the aviation trajectory; this mode allows a good understanding of the sensitivities of the main action levers
- Scenarios: the user displays already defined and parameterized scenarios; this is the easiest mode to use
- Expert: the user directly enters values for various model parameters in a CSV document; this is the mode to be used for more detailed elaboration of aviation climate trajectories

A. Getting start with Manual and Scenarios modes

To get started, if you understand French, you can visit the following link and complete the short tutorial: https://adn.isae-supaero.fr/course/view.php?id=1039

In Manual mode, discover all the sliders to fully understand their function and use. You can also display different curves.

B. Application: Analysis of a reference scenario

The objective of this section is to use the basic CAST functions to analyze the climate sustainability of an industrial scenario, represented in Figure 2. The analyses will be done for +1.5°C and +2°C, with median carbon budgets and without considering the use of BECCS (BioEnergy with Carbon Capture and Storage).

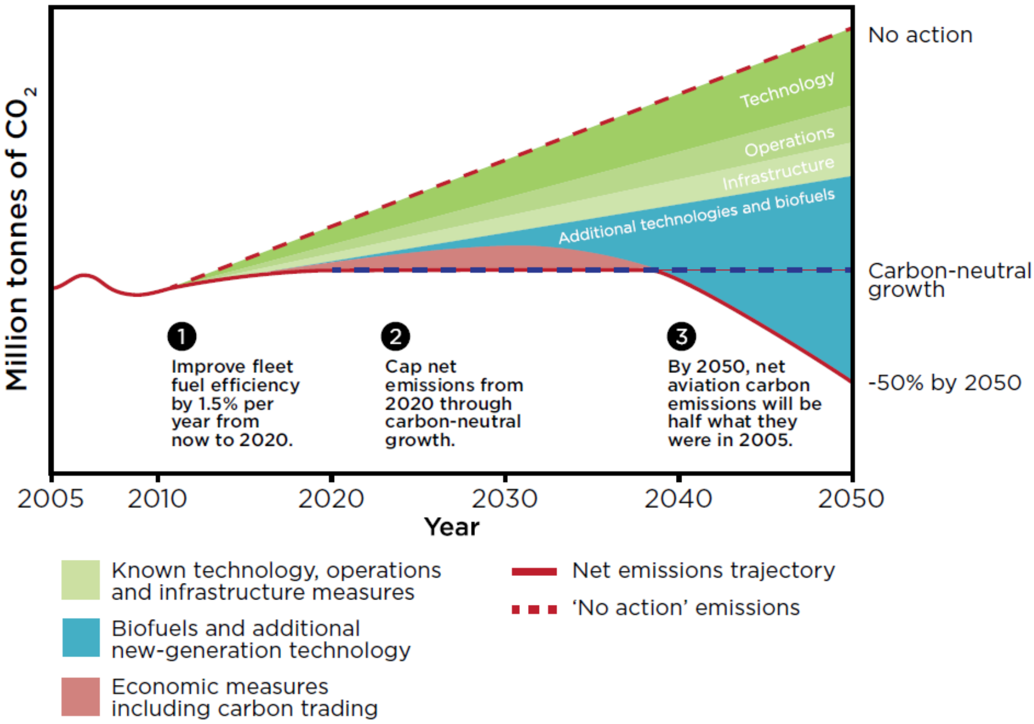

Figure 2 : Climate transition scenario proposed by aviation stakeholders (ATAG)

In Scenarios mode, select the scenario "ATAG 2009".

At first, only CO_2 emissions are considered. Select the graph "Trajectory of global CO_2 emissions". What share of the world carbon budget should be allocated to aviation for the scenario to be considered sustainable? Comment.

In a second step, the analysis is extended to non-CO_2 effects. Select the graph "Trajectory of global effective radiative forcing". What share of the world equivalent carbon budget should be allocated to aviation for the scenario to be considered sustainable? Comment.

2. Sustainable climate scenarios for CO_2 emissions

In this section, different sustainable scenarios for aviation will be modeled. The analyses will be limited to CO_2 emissions from aviation, taking into account the Covid-19 crisis. Moreover, the reference temperature considered will be +2°C, with 67% chance of success and without considering the use of BECCS.

A. Definition of three baseline technological scenarios

Many uncertainties remain concerning future technological developments for new generations of aircraft. On the one hand, technological limits are beginning to appear, for example on engine efficiency. On the other hand, technological breakthroughs, such as blended wing body, could emerge that would significantly reduce aircraft fuel consumption. Consequently, it is difficult to predict the evolution of aircraft emissions for the coming decades.

Three baseline scenarios for technological levers of action are defined in the table in the appendix. Estimate the average CO_2 emissions per Revenue Passenger Kilometer (RPK) for the aircraft fleet in 2050 and complete the table.

B. Approach 1 : Determining the share of the carbon budget required

We choose to consider a trend growth of air traffic, i.e. 3% per year.

For each technological scenario, we try to balance the resulting cumulative CO_2 emissions with a carbon budget. Determine the share of the world carbon budget that should be allocated to aviation in each case.

Complete the table in the appendix and comment on the range of variation you obtain.

What are the advantages/drawbacks of this approach?

C. Approach 2 : Determination of the sustainable development of air traffic

This time we choose to allocate 2.6% of the world carbon budget to aviation (aviation's share of world CO_2 emissions in 2019).

For each technological scenario, determine the annual growth rate of air traffic to balance the cumulative CO_2 emissions of aviation with the carbon budget allocated to aviation.

Complete the table in the appendix and comment on the range of variation you obtain.

What are the advantages/drawbacks of this approach?

In the following, the different reference technological scenarios and the associated growth rates from approach 2 will be retained.

3. Taking into account non-CO_2 effects in the scenarios

In the previous section, only CO_2 emissions were considered to define sustainable trajectories. The objective of this part is to generalize the previous method to non-CO_2 effects. For this purpose, the concept of CO_2 equivalent emissions is used.

The reference temperature considered will be +2°C, with 67% chance of success and without considering the use of BECCS. In this section, 5.5% of the global equivalent carbon budget is allocated to aviation (aviation's share of the world ERF evolution over the period 2005-2011).

Specific strategies on non-CO_2 effects can be implemented, for example to reduce contrail formation. Two assumptions are considered here:

- No specific strategy is in place
- Operational strategies are implemented ("Realistic" setting in Manual mode)

By selecting the graph "Trajectory of global effective radiative forcing", check or not the climate sustainability of the different reference scenarios of the previous part, for the two previous assumptions. Complete the table in the appendix and analyze your results.

4. Towards the concept of environmental problem shifting

The previous analyses show that, for a given carbon budget, technological improvements can ensure a higher level of air traffic. Some of these strategies are based on the use of low-carbon fuels to replace kerosene. However, there are limits to the availability of these energy resources.

To illustrate this problem, it is assumed here that the low-carbon fuels used are biofuels from biomass. Hydrogen and electrofuels are not considered in this study. It is then assumed that 100 EJ of biomass will be available in the world by 2050. Finally, it is assumed that the efficiency to obtain biofuels via biomass is 50%.

For each reference scenario, determine the amount of energy needed in 2050 from biofuels. Then estimate the share of world biomass needed. Complete the table in the appendix and comment.

Appendix: Summary table of study results

Type	Variable name on CAST	Scenario 1	Scenario 2	Scenario 3	Unit	Description	Remark
Technological parameters	Efficiency	Trend	Unambitious	Ambitious	[-]	Manual mode setting of slider for the aircraft fuel efficiency improvement	
	Operations	Pessimistic	Realistic	Optimistic	[-]	Manual mode setting of the slider for improved flight and ground operations	
	Load factor	Trend	Unambitious	Ambitious	[-]	Manual mode setting of the slider for aircraft load factor improvement	
	Energy	0%	50%	100%	[-]	Manual mode setting of the slider for the share of the fleet that will have access to low-carbon fuels in 2050	
	/				[gCO2/RPK]	Global average CO2 emissions per revenue passenger kilometer for the aircraft fleet in 2050	Read on the graph "CO2 emissions per RPK"
Part 2: Results of the carbon study	/				[%]	Share of carbon budget to be allocated to aviation for a 3% annual growth	You can directly read the value on the central pie chart
	Air traffic				[%]	Annual air traffic growth rate to balance with carbon budget (2.6% allocation)	
Part 3: Results of the carbon equivalent study	/				[%]	Share of equivalent carbon budget to be allocated to aviation without contrail strategies	You can directly read the value on the central histogram
	/				[%]	Share of carbon equivalent budget to be allocated to aviation with operational strategies against contrail	
Part 4: Results of the energy study	/				[Mtoe]	Energy in the form of biofuels consumed by aviation in 2050, expressed in Mtoe	To be found via the overall energy consumption and the decarbonation rate
	/				[EJ]	Energy in the form of biofuels consumed by aviation in 2050, expressed in EJ	1 Mtoe = 0,0419 EJ
	/				[%]	Share of biomass needed for aviation in 2050	