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Assessing Policies for the Uptake of Sustainable Aviation Fuels Using the Impact Monitor Framework †

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Abstract: The Impact Monitor Project, funded by the EU, aims to develop an impact assessment framework for European aviation. This paper uses the framework for the modelling and simulation of an impact assessment at the air transport system level, focusing on policies for the uptake of sustainable aviation fuels. It aims to demonstrate the capabilities developed by the Impact Monitor framework and its interactive dashboard application at the air transport system level.

Keywords: Impact Monitor; air transport system; demonstration

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1. Introduction

The Impact Monitor Project [1], funded by the EU, aims to develop an impact assessment framework for European aviation. Focused on environmental, economic, and societal impacts, particularly greenhouse gas emissions, air quality, and noise, it facilitates the integration of advanced design and evaluation tools. Coordinated by the German Aerospace Center (DLR), this initiative leverages digital technologies for collaborative engineering across the aviation sector, thereby streamlining the assessment processes at the aircraft, airport, and system levels.

This project defines three Use Cases that consider three assessment levels: aircraft, airport, and air transport system. This paper presents the modelling and simulation of an impact assessment at the air transport system (ATS) level, focusing on policies for the uptake of sustainable aviation fuels (SAFs). The aim is to give an interim demonstration at the ATS level of the capabilities developed by the Impact Monitor framework and its interactive dashboard application. This demonstration will be completed in the final months of the project.

Figure 1 gives an overview of the tools involved in the ATS Use Case, as well as the tool owners. This Use Case aims to demonstrate the framework, on the one hand, for three tools that have already been combined in the past for analyses, though not yet using the

framework (Scheduler, the Emissions tool, and ECOIO), and on the other hand for a new combination of tools (TRAFUMA with the other tools). Scheduler, ECOIO, and TRAFUMA analyze different dimensions of the economic impacts of policies, while the environmental impacts are covered by the Emissions tool and TRAFUMA. For the purpose of the project, Scheduler and the Emissions tool have been optimized to integrate them smoothly in the workflow.

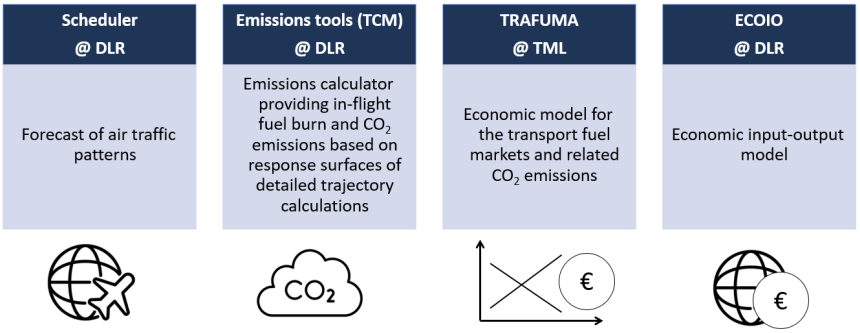


Figure 1. Tools used in the ATS Use Case of Impact Monitor.

Together, the four tools allow the impacts of policy scenarios on a range of KPIs to be assessed for the following impact categories: climate; emissions and air quality; economy; social impacts/quality of life; efficiency; and effectiveness (see also [2]).

Section 2 first describes the technical implementation of the ATS Use Case. Next, Section 3 presents the set-up and results of the demonstration exercise. Section 4 concludes the paper.

2. Technical Implementation

The Use Case aims to demonstrate the collaborative approach of Impact Monitor with the integration of the four tools and the use of collaborative strategies enabled by CPACS (Common Parametric Aircraft Configuration Schema) and RCE (Remote Component Environment) (see also [3]).

2.1. Workflow

The Use Case analyses two policy scenarios for aviation. The effects of the scenarios are determined compared to a reference scenario. The workflow is presented in Figure 2. First, based on the definition of the scenarios, TRAFUMA computes their impact on the user price of aviation fuel. The outcome is then used by Scheduler to compute the impact of the change in the fuel costs on air travel and the fleet mix. Next, the Emissions tool calculates the effects on aviation fuel consumption and the CO_2 emissions from in-flight fuel burn based on response surfaces per aircraft type, mass and flight distance. These response surfaces, called Reduced Emission Profiles, have been calculated in a pre-processing step with the Trajectory Calculation Module (TCM) [4,5]. In addition, TRAFUMA provides information on the CO_2 emissions from another perspective, namely the well-to-wake emissions while considering also indirect land use change (WTW with ILUC). Finally, ECOIO computes the broader economic impacts of the policies, based on the results of the other tools. In addition to the results that are exchanged between the tools, other results are stored for reporting using the Impact Monitor dashboard application [3].

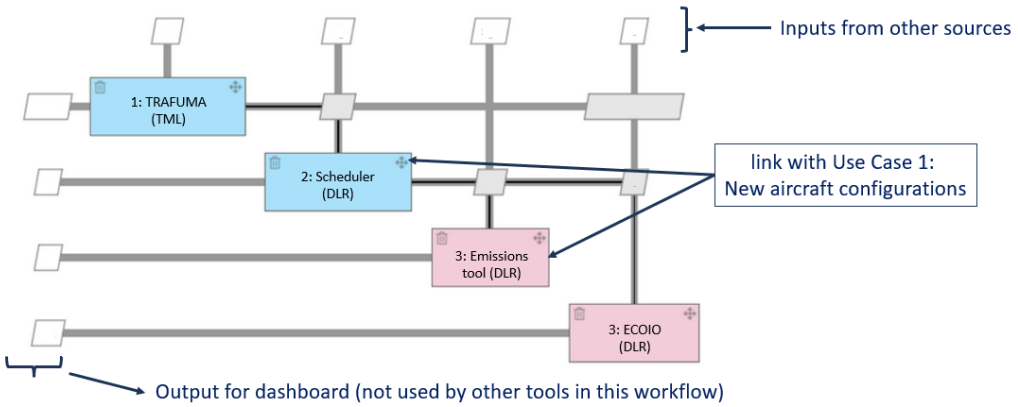


Figure 2. Set-up of computational workflow using MDAx (MDAI Workflow Design Accelerator).

The interaction with other Use Cases of the project is demonstrated with the use in Scheduler and the Emissions tool of new aircraft configurations from Use Case 1 (aircraft level) [6]. The background data of the Emissions tool are extended with new aircraft designs received from Use Case 1 in a CPACS format and processed with the TCM.

2.2. Integration of the Tools in CPACS, RCE and the Dashboard Application

The four tools of the ATS Use Case are integrated in CPACS and RCE, as well as the dashboard application. In order to conduct the case study, the CPACS data model has been extended (Figure 3). For TRAFUMA, a new <airTransportSystem> element has been created under the <studies> node and for ECOIO the element <economicImpactAssessment> has been created under the same node. In both cases, the new nodes contain a range of sub-nodes. In addition, the new <toolspecific> node contains information about the background scenarios for TRAFUMA and the Emissions tool. For Scheduler and the Emissions tool, extensions have been made to the previously existing nodes. The new CPACS structure is flexible and can be extended to include future ATS study elements as required, providing good scalability for future projects and research activities.

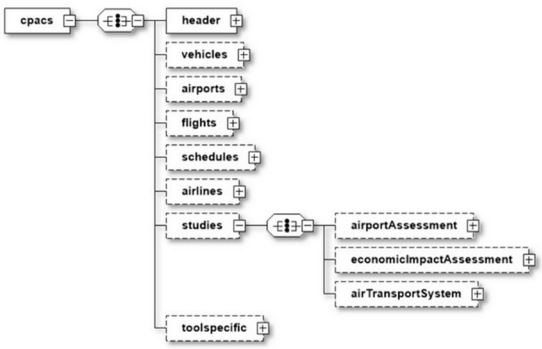


Figure 3. CPACS extension for the ATS Use Case.

As in all the Use Cases of Impact Monitor, RCE is used with the aim of remotely running the tools. In this process, a verification step has been integrated in which the tool owners can verify the tool results before they are used in the next steps of the workflow.

3. Demonstration Exercise: Scenarios for the Uptake of Sustainable Aviation Fuels

The feasibility of the workflow and cooperation among the tools to obtain and refine the outcomes are demonstrated while analyzing the impacts of two policy scenarios for

2035 and 2050: the introduction of a global carbon tax in aviation, and the implementation of a global blending mandate for sustainable aviation fuels.

The main focus of the exercise is the demonstration of the Impact Monitor framework, rather than the exact finetuning of the scenario components. The assumptions of the scenarios that are detailed next should therefore be considered as exploratory. One of the advantages of the framework is that it can be used to simulate the impacts of policy scenarios under alternative assumptions in a structured and documented way.

3.1. Scenario Definition: Reference Scenario and Two Policy Scenarios

The impacts of the two policy scenarios are evaluated in comparison with a reference scenario. The fuel consumption in the reference scenario is based on the stated policies scenario (STEPS) of the IEA [7] and scenario S1 of the impact assessment of the 2040 Climate Target in the EU [8] for road and maritime transport. For aviation, the DLRCON scenario of the DLR is used [9]. The policies included in the reference scenario for 2035 and 2050 are as follows:

- The tax levels in 2015 (assumed to remain constant in real terms).
- Aviation has to surrender ETS emission allowances for the CO_2 emissions of flights within and between the countries of the European Economic Area (EEA), Switzerland and the UK. Maritime transport is covered by the ETS. In addition, the EU ETS2 applies, with road transport as one of the sectors covered. The future price of the emission allowances in the EU ETS and EU ETS2 is taken to be 200 EUR/tonne CO_2.
- The EU CO_2 emission performance standards for road vehicles apply. In combination with the EU ETS2, this leads to an important electrification of road transport, and a substantial decrease in the non-electric fuel demand of the sector in 2035 and 2050 compared to now.
- Policies regarding renewable energy:
    - For non-European countries, the share of renewable fuels in the transport sector is based on the "stated policies" scenario of the IEA [7].
    - For the EU in 2035, a policy similar to the Renewable Energy Directive III is assumed to apply in the reference scenario, with a target share of 60% for transport. The multipliers and constraints on the fuels allowed are the same as in the REDIII.
    - For the EU in 2050, a renewable energy share of 90% is assumed for road transport.
    - The share of renewables in electricity generation is taken to be 77% in 2035 and 89% in 2050 (scenario S1 of [8]).

As the aim of the demonstration exercise is to explore the impacts for the uptake of renewable fuels in aviation, no separate target or additional policies are assumed to apply to this sector in the reference scenario. Similarly, it is assumed that there is no separate target for maritime transport.

Two policy scenarios are explored in the demonstration exercise. The definitions should be seen as exploratory. Nor are they designed in order to attain the same emission reduction in any given year. In both scenarios, all other policy instruments are the same as in the reference scenario, unless mentioned otherwise.

- SC_blending: a blending mandate is introduced for aviation and maritime transport.
    - Aviation: For the EU, this scenario is broadly in line with REFuelEU Aviation: 20% SAF in 2035 and 70% SAF in 2050; for the fuels bought in the EU, a minimum share of renewable fuels of non-biological origin (RFNBO) applies: 5% in 2035 and 70% in 2050. No food- and feed-based fuels can be used in

aviation. For the rest of the world, the overall blending mandate is similar, but no sub-mandate is assumed to apply for RFNBO.

- o Maritime transport: for fuels bought in the EU, the scenario imposes a blending mandate of 25% in 2035 and 90% in 2050.

- SC_ENVTAX: an environmental tax is levied on aviation fuels in 2035 and 2050, depending on the WTW with ILUC CO_2eq emission factors. The tax is assumed to equal 200 EUR/tonne CO_2eq. In this scenario, aviation is no longer included in the European emission trading systems.

3.2. Tool Parameters

For the demonstration exercise TRAFUMA has been recalibrated for air transport such that the price elasticities of fuel demand in the TRAFUMA market segments are in line with those of Scheduler and the Emissions tool. For the other model parameters, the sources and assumptions are taken from previous analyses with the four tools and have been kept unchanged for this project, as the focus of the project lies on the demonstration of the Impact Monitor framework. They are documented in [9–12]. Costs for SAF types not yet considered in previous analyses were taken from [8].

3.3. Scenario Results

The combination of tools covers various metrics describing the scenario results. Here, we show only a selection. The graphs have been produced with Impact Monitor's dashboard application.

TRAFUMA calculates the impact of the policy scenarios on the fuel costs (Figure 4). In 2035, the impact of the blending mandate on the fuel costs for fuel bought in the EU is relatively small. As the SAF count for the broader REDIII transport target, they are cross-subsidized by higher fossil fuel costs not only in aviation but also in the other transport sectors. Moreover, no ETS allowances need to be surrendered for SAF. Outside of Europe in 2035 and for all flights in 2050, when the blending mandate is much stricter, it leads to a substantial increase in fuel costs. The ENVTAX scenario, which imposes a tax of 200 EUR/tonne of CO_2 emissions globally (on a WTW with ILUC basis) leads to similar prices in all aviation market segments. The ETS no longer applies for aviation in this scenario, leading to only a small change in this segment, which is related to the fact that the tax is now based on the WTW with ILUC emissions of the fuels that are used. In the other market segments, the price increases are substantial.

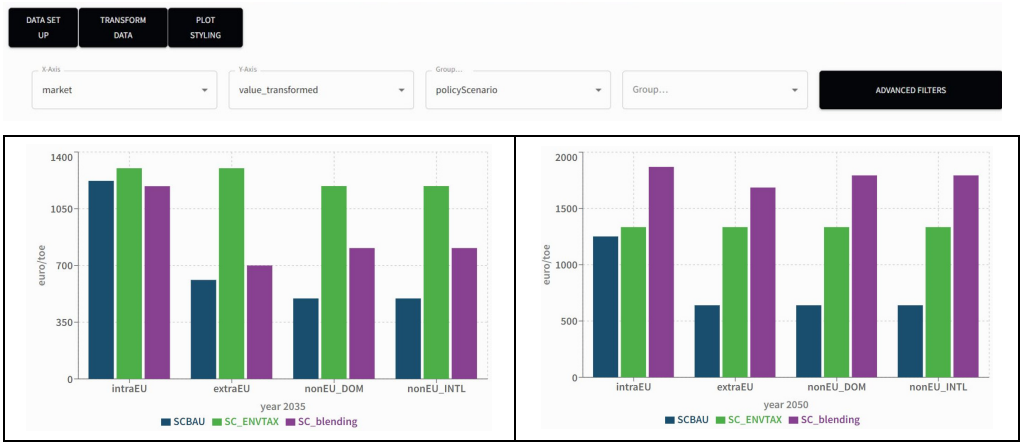


Figure 4. Fuel cost in the reference scenario and the two policy scenarios (euro2016/tonne of oil equivalent). Source: TRAFUMA.

The scenarios lead to the following impact on the number of revenue passenger kilometres (RPK) and flights for the whole fleet (Figure 5): in 2035, the SC_ENVTAX scenario leads to the lowest level of RPK and flights, whereas in 2050, the lowest demand comes through the scenario with a blending mandate.

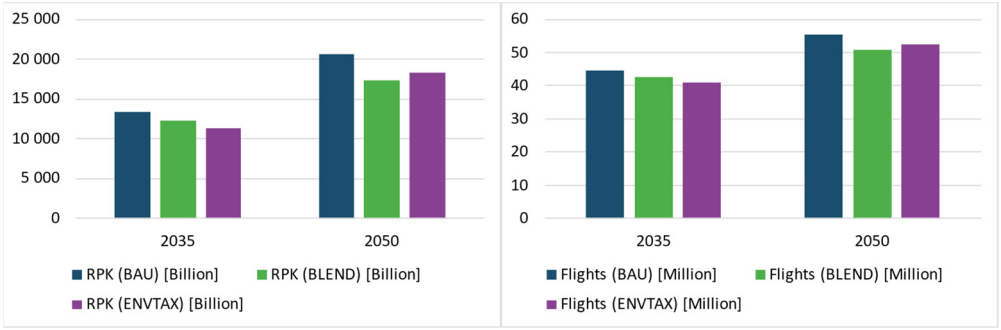


Figure 5. Revenue passenger kilometres (**left**; in billions) and number of flights (**right**; in millions) in the reference scenario and the two policy scenarios. Source: Scheduler.

Regarding the impact on the fuels used, which is calculated with TRAFUMA, with the blending mandate, the shares of the different types of fuels are in line with the blending mandate. In the ENVTAX scenario, the level of the tax that is assumed does not lead to an uptake of SAF.

Concerning the CO_2 emissions for in-flight fuel burn for the whole fleet, the following impacts are simulated: in 2035, the best CO_2 result is achieved through the environmental tax scenario, whereas in 2050, the blending mandates yield the lowest emissions.

As there is no uptake of SAF in the environmental tax scenario, all CO_2 emission reductions are related to the reduction in fuel demand. In the scenario with the blending mandate, emissions are reduced via two mechanisms: a reduction in fuel demand (see Figure 6), and the reduction in the emissions from the WTW with ILUC perspective. Figure 7 gives the percentage change in the average WTW with ILUC emissions per tonne of oil equivalent (toe) of fuel that is consumed for the scenario with the blending mandate. For the environmental tax scenario, there is no change in the emission intensity of the fuels used.

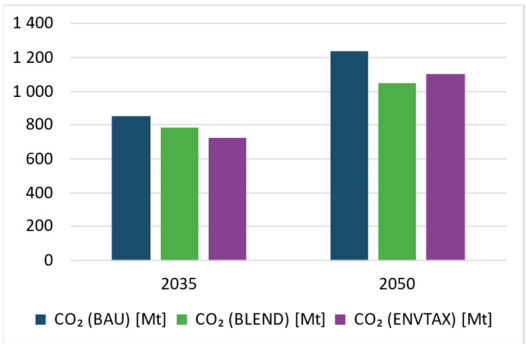


Figure 6. CO_2 emissions from in-flight fuel burn (million tonnes CO_2). Source: Emissions tool.

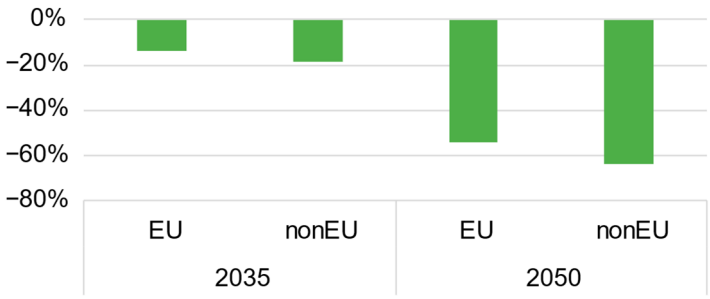


Figure 7. Average CO_2 emissions per tonne of oil equivalent—percentage change compared to the baseline scenario. Source: TRAFUMA.

To investigate the cost-effectiveness of the policies in the two scenarios, TRAFUMA calculates the social cost per tonne of CO_2 abated (Figure 8). This is calculated by taking the sum of the change in consumer surplus, producer surplus and government revenue, and by dividing this sum by the change in emissions (WTW with ILUC perspective). As can be expected based on the previous literature, the social welfare cost per tonne abated is high for the blending mandates, which impose a costly technology (SAF) to reduce emissions. Under the environmental tax scenario, emissions will be reduced up to the point where the marginal cost of an additional unit of emission reduction equals the level of the environmental tax (200 EUR/tonne CO_2). The resulting average social welfare cost is about 100 EUR/tonne CO_2. These social welfare costs can be compared with those in other sectors, for other policies or for other levels of the two policies considered here. By comparing them with the benefits of emission reductions, they can also be used in social cost–benefit analyses to evaluate the policies and compare them with other policies.

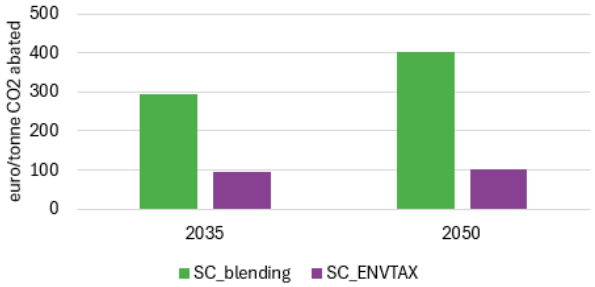


Figure 8. Social welfare cost per tonne of CO_2 emission abated (WTW with ILUC perspective)—euro2016/tonne CO_2 abated. Source: TRAFUMA.

Finally, the ECOIO tool presents information on the economic impacts of the policy scenarios. Since both the blending mandates and the environmental taxes lead to a lower demand for air travel, the gross value added and employment created by the aviation industry decrease in both scenarios compared to the business-as-usual scenario. Figure 9 shows these results in detail for the European Union, broken down by each sub-sector of the aviation industry (e.g., air transport = AT), scenario, and year. The value added and employment effects are an aggregate of direct, indirect, and induced effects. Direct effects result from activities within the aviation industry itself, while indirect effects arise from the activities of suppliers to the aviation industry (e.g., fuel providers). Induced effects, on the other hand, are generated by the consumer spending of employees in both the direct and indirect sectors, which in turn stimulates further economic activity.

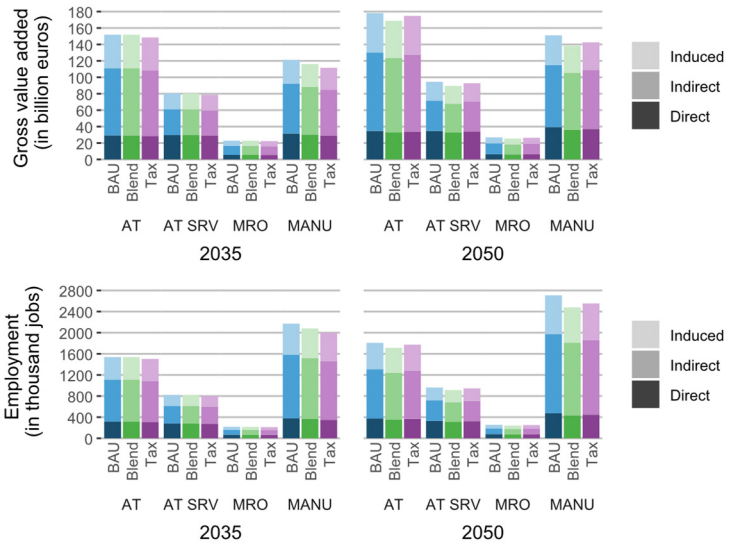


Figure 9. The economic impacts of the policy scenarios in the European Union. Source: ECOIO. Notes: AT = air transport, AT SRV = air transport-related services (e.g., airport services, air traffic management), MRO = maintenance, repair and overhaul, MANU = manufacture of aircraft and aircraft components; BAU: reference scenario; Blend: scenario with blending mandate; Tax: environmental tax scenario.

4. Concluding Remarks

The previous sections have demonstrated that the Impact Monitor framework can indeed be used for scenario studies at the ATS level. While some final steps still need to be taken to optimize the workflow further, the intermediate results already confirm that the framework can indeed contribute to the aims that were set forward at the beginning of the project: an enhanced efficiency and productivity, and the associated cost reduction, the facilitation of innovation and knowledge sharing, and the possibility to contribute to improved decision making.

Finally, the policy scenarios that were presented in Section 3 should be considered to be exploratory. They are solely intended to demonstrate that the tools can be combined in the framework as well as to show the type of metrics that can be investigated with the different tools, and how they can complement each other in this respect. A full evaluation of SAF policies would also require the consideration of a wider range of policy assumptions: different definitions of the policies than the ones considered here (e.g., different tax levels, different modalities for the blending mandates, etc.) as well as the consideration of other policy instruments (e.g., subsidies). The advantage of the Impact Monitor framework is that it greatly facilitates such additional work once the workflow with the different tools has been set up. Moreover, it allows additional tools to be brought in that can shed light on additional policy impacts, such as, for example, tools that inform on the reductions of the non-CO_2 climate impacts of SAF policies.

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