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Abstract

Green-GEAR aims at enabling and incentivising optimum green trajectories and airspace use through new ATM procedures; it develops three new SESAR Solutions to this end.

The present document is the initial version of Operational Service and Environment Definition (OSED), providing the initial description of the operational and technical environment associated with the SESAR solution for Green route charging, targeted at achieving Technology Readiness Level 2.

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Green-GEAR

GREEN OPERATIONS WITH GEOMETRIC ALTITUDE, ADVANCED SEPARATION & ROUTE CHARGING SOLUTIONS

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1 Executive summary

The Green-GEAR project aims to develop innovative ATM (Air Traffic Management) procedures that enable and incentivise the use of optimum green trajectories and efficient airspace usage. This is achieved through a new SESAR Solution called Green route charging (GRC), specifically targeted at achieving Technology Readiness Level 2 (TRL2).

This document is the initial OSED, and the concepts presented here will be updated after the completion of validation exercises, and described in detail in the deliverable D5.5, Final OSED.

SESAR Solution Description: the Green Route Charging (GRC) Solution introduces new en-route charging mechanisms: Initial and full. Initial Solution mechanisms are aimed at reducing CO_2 emissions and improving horizontal flight efficiency. These mechanisms eliminate the incentive for airlines to detour to avoid higher charges, thus promoting environmentally friendly flight paths. The Full GRC Solution investigates the possibility of reduction of total climate impact of aviation (both CO_2 and non-CO_2), through the avoidance of climate hotspots as defined by algorithmic climate change functions.

Operational and Technical Environment: the GRC Solution operates within the 41 EUROCONTROL contracting States and adheres to the Multilateral Agreement on Route Charging. It specifically targets en-route airspace, influencing flight planning and route selection through economic incentives.

Key Assumptions: assumptions include the belief that the modulation of route charges can effectively reduce CO_2 emissions and enhance airspace efficiency, and eventually reduce the total climate impact of aviation. These assumptions will require validation at higher maturity levels before being formalised into requirements.

Stakeholders and Performance Contributions: the Solution impacts various stakeholders including States, Air Navigation Service Providers (ANSPs), EUROCONTROL's Central Route Charges Office (CRCO), the Network Manager (NM), and airlines. It aims to balance capacity supply and demand, enhance airspace efficiency, and ensure revenue neutrality for ANSPs.

Maturity Status: the GRC Solution is at the initial development stage, with concepts to be validated through modelling and stakeholder consultations, with the aim of reaching the TRL2. The outcomes of these validations will inform further development activities.

2 Introduction

2.1 Purpose of the document

The purpose of this Operational Service and Environment Definition (OSED) document is to provide a comprehensive description of the operational and technical environment associated with the SESAR Solution for Green Route Charging (Solution number 0408), targeted at achieving Technology Readiness Level 2 (TRL2). This document aims to outline the foundational elements required to understand and implement the Green Route Charging (GRC) mechanism, detailed insights into the operational scenarios, key assumptions, and the environment in which the Green Route Charging Solution will operate [22]. GRC is designed to incentivise and enable optimum green trajectories and efficient airspace usage through innovative ATM procedures.

The SESAR Solution development lifecycle is structured to progressively increase the maturity of the Solution, with the ultimate goal of delivering it for industrialisation and deployment. The OSED is a critical technical deliverable at the TRL2 stage, serving as a key reference for stakeholders involved in the Solution's development and future implementation. This document will facilitate the understanding and alignment of various stakeholders, including consortium members, SESAR project representatives, and regulatory bodies, by providing a clear and structured overview of the Solution's operational concept, technical environment, and expected performance benefits. It sets the stage for further validation and development activities that will be detailed in subsequent project deliverables and plans.

2.2 Scope

The scope of this OSED document is to provide a comprehensive description of the GRC Solution. This document delineates the new operating methods, the operational and technical environments, and the foundational elements necessary for the development and validation of the GRC Solution. These concepts will be developed and assessed through the project’s research as laid out in the Exploratory Research Plan (ERP).

Operational scope

The GRC Solution is primarily a strategic concept aimed at influencing the long-term planning and operational strategies of airspace users. It provides economic incentives through route charges to encourage the selection of environmentally friendly trajectories and optimal use of airspace. By adjusting route charges based on environmental impact and congestion, the GRC Solution aims to reduce CO_2 emissions and enhance airspace efficiency.

The operational environment encompasses the 41 EUROCONTROL contracting States that adhere to the Multilateral Agreement on Route Charging, specifically focusing on en-route charges. The GRC Solution is applicable to en-route airspace, where it can effectively influence flight planning and route selection. It does not apply to flights with a maximum take-off weight (MTOW) below 2000 kg, military flights, flights in visual flight rules airspace, and circular flights.

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The operational environment covers the en-route airspace managed by the EUROCONTROL contracting states. The technical environment includes the existing framework of the SES performance and charging scheme and aligns with the principles set by the International Civil Aviation Organization (ICAO) [23].

The following stakeholders would be impacted and/or involved in the new process:

- **States:** Consult with air navigation service providers and airspace users (AUs), adopt national performance plans, calculate unit rates, and decide on the application of modulation of charges.
- **Air Navigation Service Providers (ANSPs):** Inform national supervisory authorities/States on planned costs and investments, report on actual costs and traffic, and provide traffic counts to CRCO.
- **EUROCONTROL's Central Route Charges Office (CRCO):** Operates the route charges system, calculates charges, collects and disburses charges, and supports States in the calculation of unit rates.
- **Network Manager (NM):** Optimises traffic flows by balancing capacity supply and demand, ensuring safe and efficient operations.
- **Airlines:** Plan and operate flights, pay route charges, and strive to reduce operating costs and environmental impact.

Methodology and validation

The GRC Solution employs a combination of hypothesis testing and solution searching methodologies. The initial concepts will be developed and assessed through modelling and stakeholder consultations as is outlined in the Exploratory Research Plan (ERP). The validation exercises will test the feasibility and effectiveness of the GRC mechanisms in realistic operational scenarios to ensure their robustness and scalability.

Research Questions and Hypotheses:

- How can modulation of route charges reduce CO_2 emissions and enhance airspace efficiency?
- What are the potential economic and environmental benefits of optimised route designs?
- How effective are green route charges in incentivising environmentally friendly operations?

The outcomes of these validation exercises will inform further research and development activities, supporting the transition of the GRC Solution from concept to operational reality.

2.3 Intended readership

This document is aimed at the following stakeholders:

- All Green-GEAR consortium members who are contributing directly to the Solution research or contributing to related Solutions or work packages in the project (Airbus, DLR, EUROCONTROL, NATS, NLR, UNITS, UoW),
- Relevant SESAR projects,

- SJU Programme representatives, as the owner and final approver of this document.

2.4 Background

This section presents the background on which the Green-GEAR project is building, focusing on previous work and existing systems that have influenced the project's direction [21].

2.4.1 EUROCONTROL Route Charging System

The Green-GEAR project builds upon the existing EUROCONTROL route charging system, a regional cost-recovery mechanism adhering to ICAO's charging policies and the Single European Sky regulations [23] [24]. EUROCONTROL contracting States apply a regional common route charging system specifically for en-route charges. Initially based on historical costs, the system moved to forecast costs in 1983, introducing the concept of under and over recovery of costs. The establishment of the Single European Sky in 2004 emphasised transparency and economic regulation, leading to the adoption of the determined costs method alongside the existing full cost recovery method. In 2020, the calculation method transitioned from charging on filed route to charging on actual route flown, improving the cost-relatedness of revenue for ANSPs and enhancing airspace efficiency by eliminating incentives for filing optimised flight plans that are not always adhered to.

The purpose of the shift to actually flown route was twofold: to improve the cost-relatedness of revenue for the ANSPs and to increase predictability and efficient use of airspace. This change aimed to remove the incentive for airlines to file "route charges optimised" flight plans, which were not always adhered to and often led to less efficient use of airspace.

2.4.2 Origin-destination charging

The project also incorporates elements from the Origin-destination charging (ODC) mechanism, which aims to eliminate detouring incentives. Unlike the common unit rate system, ODC allows ANSPs to control their unit rates and focuses on reducing CO_2 emissions compared to the current charging on actual route system. The ODC concept was originally published under the name FRIDAY (Fixed Rate Incorporating Dynamic Allocation for optimal Yield) [25]. ODC aims to ensure that route charges are more predictable and environmentally driven, providing a fixed charge for routes based on the great circle distance between origin and destination airports, thus reducing the incentive to detour for cost-saving purposes.

2.4.3 Previous Research Projects

This project builds on a foundation of prior exploratory research activities both within and outside SESAR and falls within the scope of the effort made by the European Green Deal, the overarching policy framework striving for climate neutrality by 2050, which emphasises reducing emissions across various sectors, including aviation. Notably, several significant past projects have laid the groundwork:

- **SATURN (Strategic Allocation of Traffic Using Redistribution in the Network)**: Focused on the modulation of en-route charges to redistribute traffic across Europe, providing initial insights into how pricing strategies can influence traffic flow [26].

- **ADAPT (Advanced Prediction Models for Flexible Trajectory-Based Operations)**: Explored advanced prediction models aimed at enhancing flexible, trajectory-based operations, providing a basis for adaptive decision-making in air traffic management.
- **Pilot3 (from Clean Sky 2)**: Contributed by integrating environmentally focused initiatives under the Clean Sky 2 umbrella, emphasising sustainability in aviation through innovative approaches and technologies.
- **COCTA (Coordinated Capacity Ordering and Trajectory Pricing for Better-Performing ATM)**: Provided an in-depth examination of coordinated capacity ordering and trajectory pricing, aiming to improve air traffic management (ATM) performance through strategic pricing and capacity management.
- **CADENZA (Advanced Capacity and Demand Management for European Network Performance Optimization)**: Focused on reducing air traffic emissions and improving overall network performance through enhanced demand-capacity balancing strategies.
- **ATM4E**: Explored the feasibility of a concept for environmental assessment of ATM operations, working towards environmental optimisation of air traffic operations in the European airspace, considering climate, air quality, and noise impacts.
- **CONCERTO**: Currently running, aims to make eco-friendly flight trajectories an everyday occurrence, reducing both CO_2 and non-CO_2 emissions from aviation by integrating green Air Traffic Control (ATC) capacities with appropriate automation.
- **GEESE**: Currently running, aims to develop an initial concept of operations for enabling Weather-Efficient Routing (WER) from Europe to the North Atlantic, analysing safety aspects and impacts on legacy systems.
- **CICONIA**: Currently running, focuses on reducing aviation’s climate effects through innovative CONOPS, closely examining non-CO_2 effects and exploring methods to measure them.

These preceding and currently ongoing projects contribute valuable insights and methodologies that inform the development of this project's route charging mechanisms. They illustrate the use of pricing mechanisms to effectively manage air traffic and foster environmentally sustainable operations.

2.4.4 CLIMaCCF / FlyATM 4E and ALARM Projects

The consortium plans to use the CLIMaCCF V1.0 Python library for defining climate hotspots, which is a product of the FlyATM 4E and ALARM projects [27]. This library computes individual and merged non-CO_2 algorithmic climate change functions (aCCFs) and is still under development and validation. These projects provide advanced climate science tools that allow the Green-GEAR project to address both CO_2 and non-CO_2 emissions in its route charging mechanisms. By leveraging these models, the project aims to enhance the accuracy and effectiveness of its environmental impact assessments.

2.5 Structure of the document

The Initial OSED describes the GRC Solution for en-route air navigation services and constitutes project deliverable D5.1.

Section 2 (this section) provides the context for the project concept.

Section 3 is the main section that defines the GRC Solution, which is split into an initial Solution – for which 2 options are explored – and a full (longer term) Solution. The concept summary explores introduces different options, highlighting their commonalities and specificities:

- Initial Solution: charging aimed at reducing CO_2 emission, with two methods:
  - Modulation of route charges (MRC), that adjusts the charges to reduce CO_2 impact at flight/city-pair level, while addressing the airspace congestion.
  - Combination of Origin-destination charging (ODC) with MRC, that establishes an identical baseline charge for all routes of a given city-pair, based on the Great Circle Distance (GCD), on which MRC is then applied.
- Full Solution: charging aimed at reducing the combined effects of both CO_2 and non-CO_2 emissions.

The detailed concept describes the current charging mechanism, compares the current and future operating methods, and provides an overview of the future roles and responsibilities.

Section 4 states the assumptions under which the Solution is being assessed at this TRL level.

Appendix A defines the Benefit Impact Mechanism (BIM) for the concept, showing how the SESAR Solution contributes to the delivery of the expected performance benefits.

A Final OSED will include an update to this document, constituting project deliverable D5.5.

2.6 Glossary of terms

Term	Definition	Source of the definition
En-route charging zone	A volume of airspace that extends from the ground up to - and including - upper airspace, where en-route air navigation services are provided and for which a single cost base and a single unit rate are established.	Single European Sky (SES) performance & charging scheme
Unit rate	The unit rate of charge is the charge applied in a charging zone to a flight.	EUROCONTROL 2022
Route charge	The route charge is a levy that is designed and applied specifically to *recover the costs* of providing facilities and services for civil aviation.	ICAO Doc 9082

Term	Definition	Source of the definition
Cost base	The cost base for en-route charges consists of the determined costs related to the provision of air navigation services in the charging zone concerned. Determined costs are the costs determined by the Contracting States at the level of the charging zone. These are the costs to be shared among airspace users.	SES performance & charging scheme EUROCONTROL 2022
Modulation of charges	"Member States may, on a non-discriminatory and transparent basis, modulate air navigation charges for airspace users to: (a) optimise the use of air navigation services; (b) reduce the environmental impact of flying; (c) reduce the level of congestion of the network in a specific area or on a specific route at specific times; (d) accelerate the deployment of SESAR ATM capabilities in anticipation of the time period set out in the common projects referred to in Article 15a(3) of Regulation (EC) No 550/2004,… Member States shall ensure that modulation of charges in respect of points (a) to (c) of this paragraph does not result in any overall change in annual revenue for the air navigation service provider compared to the situation where charges would not have been modulated. Over- or under recoveries shall result in an adjustment of the unit rate in year n+2."	SES Performance & charging scheme
Performance & charging scheme	Commission Implementing Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky [24] and repealing Implementing Regulations (EU) No 390/2013 and (EU) No 391/2013 (Text with EEA relevance.)	SES Performance & charging scheme

Table 1: glossary of terms

2.7 List of acronyms

Term	Definition
aCCF	algorithmic climate change function
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
AU	airspace user
CANSO	Civil Air Navigation Services Organization
CAPEX	Capital expenditure
CORDIS	Community Research and Development Information Service
CRCO	Central Route Charges Office
D<*no.*>	Deliverable <*no.*>
D	(delivery date)
DES	Digital European Sky
EC	European Commission
ER	Exploratory Research
ERP	Exploratory Research Plan
EU	European Union
GDPR	General Date Protection Regulation
GNSS	Global Navigation Satellite System
Green-GEAR	Green operations with Geometric altitude, Advanced separation & Route charging Solutions
GRC	Green route charging

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Term	Definition
M<*no.*>	project month <*no.*>
MS<*no.*>	milestone <*no.*>
NM	Network Manager
NSA	National Supervisory Authority
ODC	Origin-destination charging
OPEX	Operational expenditure
OSED	Operational Service and Environment Description
PDF	Portable Document Format
Q<*no.*>	(calendar) quarter <*no.*>
RP	Reference period
SES	Single European Sky
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SP	Stated preference
SRIA	Strategic research and innovation agenda
T<*no.*>	task <*no.*>
TRL	Technology Readiness Level
UK	United Kingdom [of Great Britain and Northern Ireland]
UKRI	UK Research and Innovation
WA	Working Area
WP<*no.*>	Work package <*no.*>
WTP	Willingness to pay

Table 2: list of acronyms

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3 Operational service and environment definition (OSED)

This chapter describes the Green Route Charging (GRC) [0408] Solution, for which the Initial and Full Solution are being developed and tested for feasibility [22].

3.1 SESAR Solution Green Route Charging: a summary

The **Initial Solution** proposes a novel **route charging mechanism** aimed at reducing the **horizontal inefficiency** due to difference in unit rates. Meaning to remove the incentive of flying detours to avoid more expensive airspace along the shorter route, and thus reduce the environmental impact. The Solution will need to comply with the EU and ICAO rules and regulations.

The **Initial Solution** proposes a novel en-route **route charging mechanism** aimed at improving **horizontal flight efficiency and reducing the resulting CO_2 emissions**. CO_2 emissions are assumed to be a proxy for flight distance. Vertical flight efficiency is not modelled at this TRL level.

The Solution addresses the **strategic phase of flight**, providing a **price signal** to AUs that will enable more efficient flight planning, environment and capacity wise, also resulting in better predictability and optimised use of capacity for ANSPs.

Other **ATFM phases** are not covered, as the setting of the unit rates for route charging is a strategic process that needs to be stable for at least a year of operations. The impact of the Solution on the daily operations will be assessed during the validation exercises in this project, which will then inform the further research needs for the higher TRL levels.

From a **regulatory perspective**, the Solution must comply with the EU and ICAO rules and regulations (e.g. no discrimination, cost relatedness, proportionality, and revenue neutrality…) [23] [24].

Two options are explored in the Initial Solution:

- Introducing a **'Modulation of route charges' (MRC)** mechanism, applied to the current trajectory-based route charges. Modulation factor M is determined for each route of a given origin-destination traffic flow, with the objective to reduce the environmental impact of flying, while addressing the airspace congestion.
- Introducing an **'Origin-destination charging' (ODC) combined with the 'Modulation of route charges' (MRC)** mechanism, where **ODC route charge** is calculated on the GCD between the origin and destination airports, therefore identical[3] for all routes of a given city pair, irrespective of the trajectory/distance flown. ODC establishes a **simple reference** for airspace users, with an identical

[3] For the distance factor of the route charge, while the weight factor remains dependant on the aircraft's MTOW, see section 3.3.1 for more details.

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baseline charge for all routes of a given city-pair. By construction, the ODC baseline aggregated at network level is a “clean baseline” that does not include “route charges optimised” trajectories and is therefore not biased by difference in trajectory lengths resulting from differences in unit rates. Applied to the ODC baseline, the modulation **factor** M_r that the MRC model produces for each route *r* of a given origin-destination traffic flow, is therefore also exempt of such bias.

The Green Route Charging **Full Solution** aims to incentivise the use of climate friendly trajectories, when considering both CO_2 and non-CO_2 emissions. A very preliminary idea would be a mechanism that would “reward” avoidance of climate sensitive areas (i.e. climate hotspots), while still leaving the flexibility of using the said areas, against a higher charge.

SESAR solution ID	SESAR solution title	SESAR solution definition	Justification (why the solution matters?)
0408	Green route charging	Charging mechanism that incentivises trajectories with minimum climate impact, while reducing airspace congestion.	The enabler for the European airspace to become the most environmentally friendly in the world, as set in the SRIA and the ambitions of the European Green Deal, and enables aviation to become more environmentally efficient [28] [29].

Table 3: Green Route Charging [0408] scope

3.1.1 Deviations with respect to the SESAR Solution definition

N/A

3.2 Detailed operational environment

3.2.1 Operational characteristics

The operational environment for the GRC Solution encompasses the 41 EUROCONTROL contracting States adhering to the Multilateral Agreement on Route Charging, specifically for *en-route charges*. These 41 contracting States include the 27 EU Member States.

The geographical scope is limited to en-route airspace. It is assumed that traffic, airspace, and airport characteristics are the same as today, as the GRC Solution can apply irrespective of the operational environment. The en-route charges in practice do not apply to flights with a maximum take-off weight (MTOW) below 2000 kg, military flights, flights in Visual Flight Rules (VFR) airspace, and circular flights.

The GRC Solution is developing a novel charging mechanism, which should change how the route charges are determined and charged, impacting the day-to-day operations only indirectly, through the modulation of unit rates.

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3.2.2 Roles and responsibilities

The roles and responsibilities are described in Table 4.

Table 4. Description of roles and responsibilities.

Role	Responsibilities
National supervisory authority (NSA)	Develops national performance plans including local performance targets, determined costs, unit rates. Defines the charging zones. Reports yearly on the execution of the scheme and at the end of each reference period.
State	Consults ANSPs and airspace users on planned costs/investments and traffic forecast in preparation of Performance Plans. Adopts national performance plans including local performance targets, determined costs, unit rates. Calculates annually the unit rates for its en-route and terminal charging zones. May decide to apply modulation of charges. Takes the necessary measures to implement and enforce the scheme.
ANSP	For the establishment of the performance plan and unit rates, informs the NSA on the planned costs and investments, the traffic forecast, and its capacity plans. Reports annually to the NSA on actual costs, actual traffic, progress of planned investments, performance achieved on the Single European Sky (SES) 4 key performance areas (Safety, Capacity, Environment and Cost Efficiency). Provides actual traffic counts to CRCO in view of the calculation of the service units and charges.
European Commission	Adopts the Performance and Charging Scheme and subsequent revisions that govern the performance of Air Navigation Services. Adopts decisions on the Union-wide performance targets for safety, capacity, environment and cost-efficiency. Approves the national performance plans and corresponding targets, reports to the legislators on the implementation of the scheme.
Performance Review Boday (PRB)	Advises the EC on the establishment of the Union-wide and local performance targets and on the assessment of the achievement of these performance targets.
EUROCONTROL - CRCO	The Central Route Charges Office (CRCO), on behalf of EUROCONTROL Members States, operates a joint system adopted by the Member States for the establishment and collection of route charges through a single charge per flight. The States signatories of the Multilateral Agreement relating to Route Charges, through the CRCO enlarged Commission and

Role	Responsibilities
	enlarged Committee, govern the Route Charges System. The CRCO calculates, in accordance with the applicable rules, the route charges due for each flight in the considered airspace. The CRCO collects the route charges and disburses the charges collected to the contracting states for the provision of the air navigation services (ANS), in accordance with the decisions of the enlarged Committee.
Central planner	The setup of modulation factors M requires an additional step to be added to the current system of route charging, which is running the GRC models (MRC or ODC+MRC) to determine the modulation factors. Furthermore, for the full GRC Solution, there is a need for a central entity that would provide the climate hotspot forecast and post-ops check inspection and check-up to make sure that the appropriate charge has been assigned to flights.
Network Manager (NM)	Optimises traffic flows by constantly balancing capacity supply and demand during all ATFCM phases.
Airline	Participates in the consultation of the EC and Member States on the implementation of the Performance and Charging Scheme. Plans and operates flights and pays the ANS charges invoiced by the CRCO.
Flight Dispatcher	The flight dispatcher is responsible for the planning of an individual flight by assessing of all boundary conditions (e.g. meteorological conditions, regulations, NOTAMs etc.) that impact the flight execution. The flight planning considers all external factors (route charges are just one component) and internal business policies and costs.
Computerised Flight Plan Service Providers (CFSPs)	CFSPs offer systems and services that assist airlines in the determination of the optimum flight trajectories in line with the airline cost/business model. These trajectories are updated in real-time to consider the evolution of the operational situation. Earlier in the planning process, OEMs develop sophisticated business planning tools (e.g. network / schedule / fleet planners). These tools must follow the evolutions of the regulatory and technological context.

3.2.3 CNS/ATS description

Route charging uses already implemented CNS/ATM services. The actually flown trajectories are necessary for the calculation of route charges and their redistribution.

In the initial Solution, the flight planning and flow management processes may be affected (e.g. there may be a need for specific exchanges of capacity information between the ANSP/NM and the Central Planner and adaptations in the AU flight planning systems), but it is not expected to have any effect on the operational control of the flight, and therefore no impact on CNS/ATS equipment.

In the full Solution, there will be a need for surveillance of the actual situation concerning climate hotspots as opposed to the predicted one.

3.2.4 Applicable standards and regulations

The current route charging system is subject to the following regulations and agreements:

- Commission Implementing Regulation (EU) 2019/317 of 11 February 2019 [24] laying down a performance and charging scheme in the single European sky and repealing Implementing Regulations (EU) No 390/2013 [30] and (EU) No 391/2013 (Text with EEA relevance.) [31].
- EUROCONTROL's Multilateral Agreement relating to Route Charges.
- ICAO's Policies on Charges for Airports and Air Navigation Services, 9th Edition, 2012, ICAO Doc 9082 [23].
- Principles for establishing the cost-base for en-route charges and the calculation of the unit rates – EUROCONTROL.

3.3 Detailed operating method

3.3.1 Previous operating method

The EUROCONTROL's Central Route Charges Office (CRCO) implements the Multilateral Route Charging System and is responsible for calculation, collection, and redistribution of route charges.

Multilateral Route Charging System in the European Union is regulated by the Implementing Regulation IR 2019/317, the Single European Sky performance and charging scheme [24]. Here we shortly explain what the route charges are, and how the route charging system works.

Route charge "is a levy that is designed and applied specifically to *recover the costs* of providing facilities and services for civil aviation." (ICAO Doc 9082, 9th edition, 2012) [23] . The Route per State Overflown route charging system is applied in Europe, which implies that a flight needs to pay a route charge to each State crossed. Each State needs to establish one or more 'en-route charging zones'. The charging zone is a volume of airspace that extends from the ground up to, and including, upper airspace, where en-route air navigation services are provided and for which a single cost base and a single ***unit rate*** are established. Unit rate is a unique tariff per service unit. The number of service units for a flight is determined by the product of the distance and weight factors. Below, this is explained in more detail.

Route charge for a flight is a sum of charges accrued over all crossed charging zones *i.*

$$R = \sum_i r_i, \qquad r_i = u_i * n_i,$$

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Where:

R is route charge;

r_i is a charge accrued over the charging zone *i;*

u_i is a unit rate for charging zone *i*; and

$n_i$is the amount of service units "consumed", which are a product of the distance (d_i) and weight (w_i) factors.

$$n_i = d_i * w_i, \qquad d_i = \frac{GCD}{100}, \qquad w_i = \sqrt{\frac{MTOW}{50}}$$

Distance factor is proportional to the great-circle distance (GCD) between entry and exit points to each of the charging zones[4]. If the origin or destination airports are within the charging zone then the distance to be used equals GCD from entry point to the airport coordinates, minus 20 km (e.g., for arrival airport). The actual route flown as recorded by the Network Manager and is used as a basis for determining the distance factor.

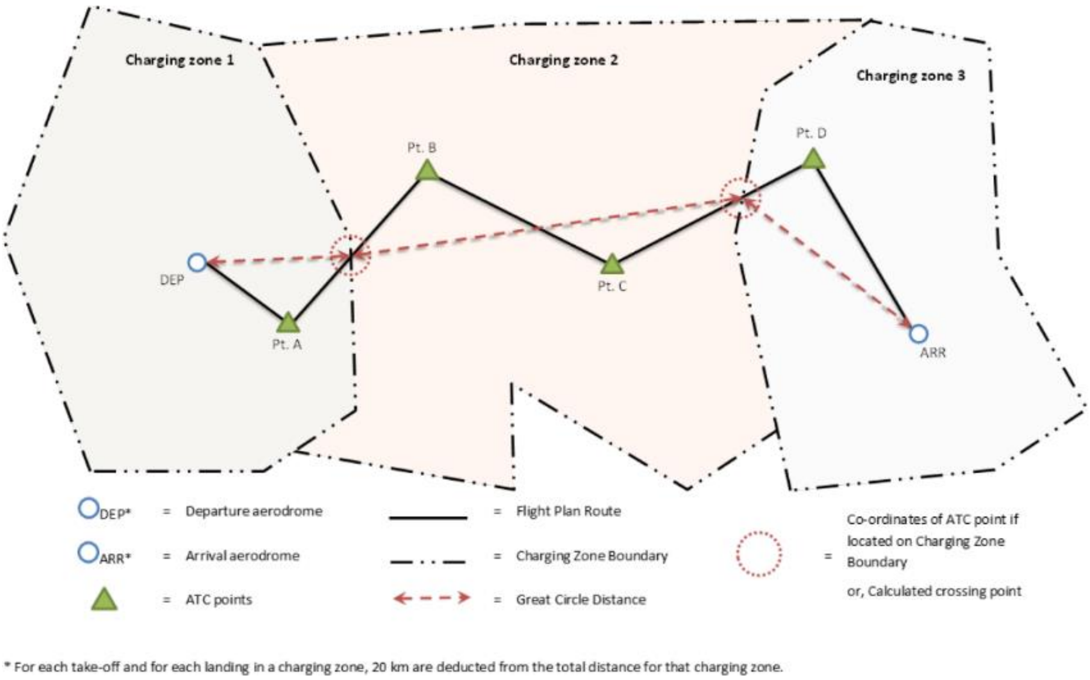

Figure 1. Establishing the distance factor for international flights (in current charging method).

[4] This should not be confused with the GCD between the departure and destination airports, which is different for international flights.

The weight factor is introduced to relate the price to be paid for the air navigation services to the productive capacities of the aircraft. Therefore, heavier aircraft are expected to pay more for the air navigation services than lighter aircraft. The weight factor is less than proportional related to the maximum take-off weight of the aircraft.

IR 2019/317 sets the performance and charging scheme under the Single European Sky for EU Member States [24]. The regulation fosters long-term improvements in the ANS (Master Plan) [32], and reduction of green-house gas emissions and optimum use of airspace. The following terms are defined within the regulation:

- Reference periods,
- Performance plans,
- Network Manager (NM) performance plan
- Incentives,
- Route and Terminal charging schemes.

Reference period (RP) is the period of validity and application of the Union-wide performance targets, duration of which should allow the implementation of multi-annual capital expenditure programmes (usually 5 years). The purpose of the RP is to provide consistency and predictability by framing the forecast and planning activities of all actors concerned in the same time horizon.

The **performance plans** are prepared by the Member States' national supervisory authorities (NSAs), substantiated by evidence of ANS future cost (OPEX and CAPEX) and announcing the underlying assumptions (traffic forecast, inflation rate, etc.). The performance targets set for an RP remain unchanged during the whole period, except in exceptional circumstances allowing revision, subject to approval by the EC (e.g. variation of traffic forecast > or < by 10% compared to plan, over the period). The performance plans, need to provide transparency of determined costs, planned investments, and to be consistent with SESAR deployment and expected performance gains. The plan should list performance targets adopted (binding) and should contain: determined costs for en-route and terminal charges; description of incentive schemes, if any; and en-route and terminal traffic forecasts. The NSAs present a draft that the State adopts, that is then sent to the EC for assessment. After the plan is adopted by the EC, it should be adopted and published by the State.

NM performance plan: The Network Manager is also subject to performance targets that must contribute to the achievement of the Union-wide performance targets. It submits a Network performance plan which is verified and adopted by the EC. It also provides relevant inputs to target setting at Union, national and functional airspace block levels, and it supports the achievement of the Union-wide performance targets by proposing operational measures in the Network Operations Plan.

Incentives: The Performance and Charging Scheme foresees that "*performance targets should be subject to incentives with a view to encouraging better performance*". These may be incentives of financial nature, for the achievement of the performance targets in the key performance area of environment. The scheme sets a capping on the value of these incentives as follows: The aggregated financial advantage or financial disadvantage from those incentive schemes shall not exceed 2 % of the determined costs of the considered year.

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The Scheme also foresees that: *"Member States may, on a non-discriminatory and transparent basis, **modulate air navigation charges** for airspace users to: … reduce the environmental impact of flying; reduce the level of congestion of the network in a specific area or on a specific route at specific times…"* [24].

Modulation of charges cannot result in any overall change in annual revenue for the ANSPs. Over- or under-recoveries are corrected by an adjustment of the unit rate in year n+2. Member States must consult airspace users and ANSPs before the application of the modulation of charges (or any other substantial changes).

Charging scheme: The **charging scheme** describes the principles for determining charging zones (en-route and terminal charging zones) and unit rates. The **unit rates** are determined by dividing determined costs by the traffic forecast. Both determined costs and the traffic forecast are defined in the performance plan. Unit rates are calculated before the start of each year of RP, they should be established by November 1st and submitted to the EC.

The determined costs are the costs that are to be financed by charges imposed on airspace users. Their scope is strictly defined in the scheme: they are established by the NSAs based on the information received from the ANSPs, and after adoption, they are fixed for the RP period. Adjustments mechanisms are made possible under strictly defined conditions, upon NSA substantiated request and subject to approval by the EC.

The charging scheme also foresees that NSA needs to define **traffic risk sharing** and a **cost risk sharing mechanisms** in case incentives schemes will be applied**.** Under the traffic risk sharing mechanism, the risk of revenue changes due to deviations from the service unit forecast (in practice deviation from traffic forecast) as set out in the performance plan, must be shared between ANSPs and airspace users. Under the cost risk sharing mechanism, differences between determined costs included in the performance plan and actual costs must be shared between ANSPs and airspace users.

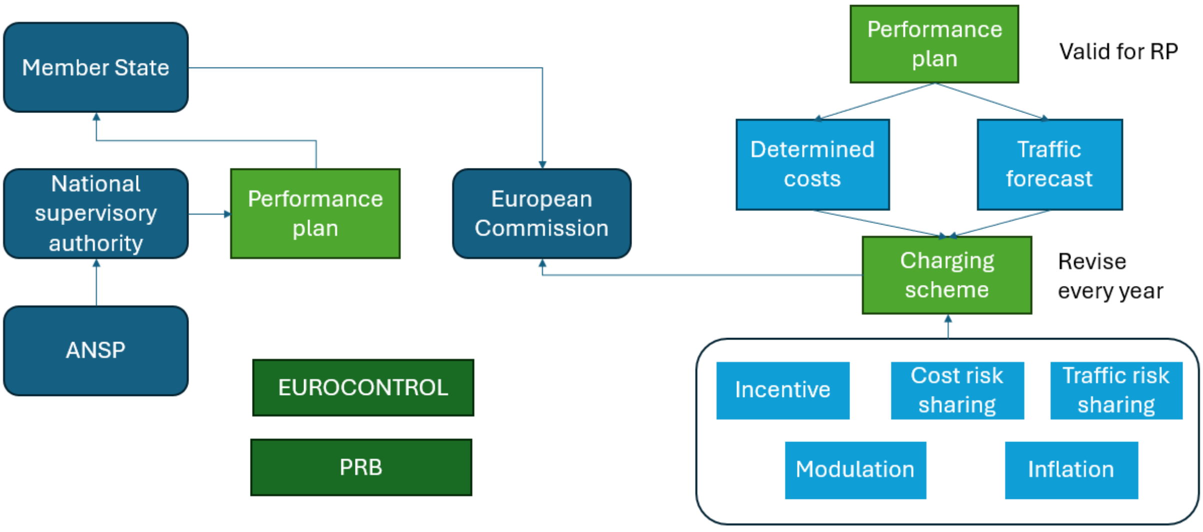

Figure 2. Performance and charging scheme stakeholders.

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3.3.2 New SESAR operating method

The GRC Solution explores the Initial and Full options, where the initial one refers to the mechanisms that could be implementable earlier than those in the full Solution. The Solution will need to comply with the EU and ICAO rules and regulations.

The **Initial Solution** proposes two novel **route charging mechanisms** aimed to remove, as much as possible, the **horizontal inefficiency** due to difference in unit rates. Making flying longer trajectories to avoid more expensive airspace along the shorter route unnecessary, and thus reducing the environmental impact. The two options proposed below need to be further detailed and their modelling verified, to see if only one of the proposed options, or both can be brought to the validation.

The **Full Solution** looks at the possibility of creation of the route charging Solution that would help reducing total climate impact of aviation.

3.3.2.1 Modulation of route charges

The main idea is to introduce the modulation of route charges to reduce the environmental impact of flying, while addressing the congestion. The unit rate and the baseline route charge would be calculated in the same manner as in the current charging mechanism. The modulation of charges is expressed as a factor M_r, defined per *route r*, that reduces or increases the total route charge of that specific *route*.

The goal is finding the set of M_r that maximise the reduction of CO_2 emissions, for which the global distance flown is taken as a proxy, while trying not to exceed the declared capacity of airports and sectors.

A *route r* is defined in a simplified way, as the list of (elementary) sectors crossed during the flight. Such simplification permits to group similar trajectories, which share the same modulation factor, in order, for the AUs, to have more flexibility within each *route*.

Figure 3 depicts how *routes* are taken into consideration. Sectors are shown as blue polygons. F1, F2, and F3 are three flight trajectories departing from O and arriving at D. F1 and F2 cross the same sectors and therefore could share the same modulation factor (although trajectories are quite different), F3 does not.

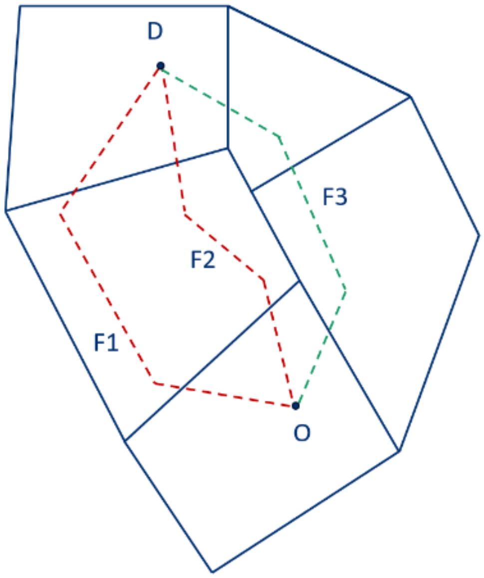

Figure 3. Identification of r*outes*.

The calculation of unit rates that would be used in the route charges calculation would remain as today, but would require the additional step of determining the modulation of route charges. The setup for collecting and distributing charges would remain the same as in the current charging mechanism.

The airspace users would know if the modulation of charges exists for different *routes* between origin-destination pairs of their interest, and they would be able to plan their routes accordingly. The route charge of a specific *route* would be equal to:

$$RC = BRC * M, \;\; where \;\; M_L < M < M_H$$

RC : route charge

BRC : baseline route charge

M : modulation factor. The factor can be constant for a yearly period, or it could vary across the day to reflect the congestion in the network.

M_L : lower limit of the modulation factor. Can be 0 if a limit is not required.

M_H : upper limit of the modulation factor. Can be defined or not specified.

The modulation factor would be primarily[5] needed on the longer routes that cross a series of States, which requires the collaboration of those States, as the individual decisions can have unintended consequences, like unaccounted traffic shift and/or congestion.

For example, in Figure 3, F3 may have decided to take the green trajectory because of lower unit rate, that compensate for the longer distance flown, with respect to the shorter red trajectories. Introducing the modulation factor, increasing the route charge for the green *route* ($M > 1$) and/or lowering the route charge for the red *route* ($M < 1$), it is possible to longer trajectories inconvenient (economically), thus reducing the environmental impact.

In addition to the modulation factor, a time displacement is also suggested. The time displacement is provided for all flights for which an adjustment of the time schedule is considered to be a cheaper option than choosing another route.

One of the outcomes of the Green-GEAR project would be a method for determining the values of M_r and the suggested displacement time (if any).

3.3.2.2 Origin-destination charging (ODC) with Modulation of route charges (MRC)

In this second option for an Initial Solution, MRC is not using actually flown route as the underlying base charging mechanism, but ODC. Below first ODC is explained in more detail, and then is explained how MRC in combination with ODC is different to MRC using current charging mechanism.

3.3.2.2.1 ODC

With ODCs the charging mechanism is split between how the charge is calculated for the AU, and how it is redistributed among the ANSPs.

ODC uses the GCD track between the origin and destination airport to determine the distance factors to be used for calculating the route charge of the airspace user (AU). The ANSPs are receiving their revenue in proportion to the services provided by the ANSPs. ODC is independent of the flight planning process, removing incentives for detours.

[5] A sector with capacity restrictions may also affect flights on short haul routes. However, these flights will have limited room for manoeuvre, due to the short distance/duration, therefore limiting the effect of the GRC incentive.

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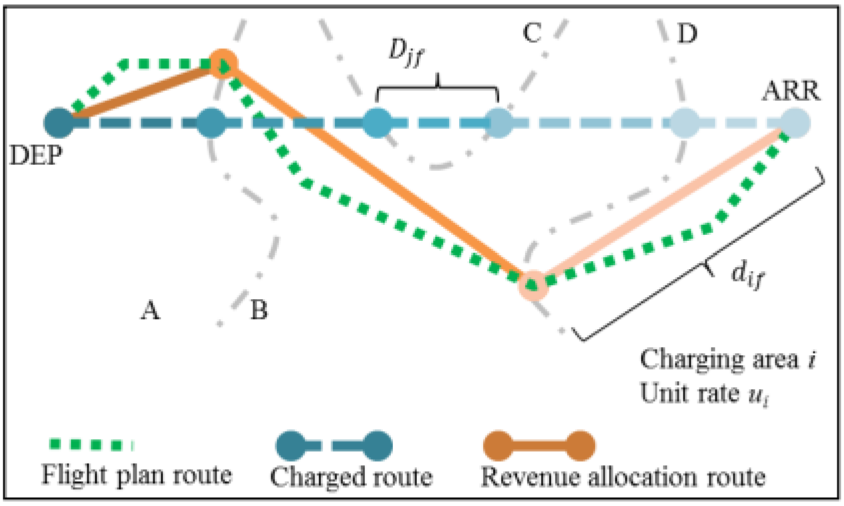

Figure 4. ODC description.

Route charge to be paid by AU

The route charge between a specific OD pair is the same for any trajectory chosen and is based on the GDC between origin and destination. The GCD passes through charging zones with unique unit rates. The route charge is calculated based on the section lengths along the GCD, the weight factor, and the unit rates of the intersected charging zones along the great circle track. This determines the total route charge to be paid for a given city-pair and aircraft type.

The route charge R_{jf} for the section *j* of the GCD is calculated in the following way for aircraft *f*:

$$R_{jf} = D_{jf} \cdot p_f \cdot U_j$$

where D_{jf} is the distance factor covered by the GCD from origin to destination crossing the charging zone *j*. U_j is the unit rate applied in the charging zone *j*. The weight factor p_f is dependent on the MTOW and is assumed to be identical to the weight factor currently being used by EUROCONTROL member states.

The total route charge to be paid for aircraft *f* is:

$$R_f = \sum_j R_{jf}$$

Charging zone revenues

The collected charges are proportionally divided over the charging zones actually crossed. The proportionality is based on the route charge according to EUROCONTROL actual route flown (or planned).

The share S_{if} from the total charge paid by aircraft *f* that is allocated to charging zone *i* is:

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$$S_{if} = \frac{r_{if}}{r_f}$$

With r_{if} being the individual charge as a function of the service units and the unit rate for the charging zone:

$$r_{if} = d_{if} \cdot p_f \cdot U_i$$

And r_f being the total charges r_{if}:

$$r_f = \sum_i d_{if} \cdot p_f \cdot U_i$$

The amount a route charging zone *i* is allocated from the collected charges from a flight is $R_f S_{if}$. The total amount each route charging zone *i* is allocated over all flights is:

$$R_i = \sum_f R_f S_{if}$$

Determining unit rates

The definition of the state-by-state unit rate would need to be changed, as the calculation of the ODC rate would need to be performed in collaboration, centrally.

The unit rates are set such that the periodic costs c_i of providing the air navigation services equals to the expected amount of revenue within that period.

With the weight factor being equal for all EUROCONTROL member states, the cost for each charging zone must be set equal to the expected revenue resulting in the equation:

$$c_i = U_i \sum_f \frac{\sum_k D_{kf} U_k}{\sum_j d_{jf} U_j} d_{if} p_f$$

Using a numerical method (e.g. Newton method using difference formulations) the set of equations can be solved to get the set of unit rates U_i. This method converges quickly to a stable set of unit rates.

3.3.2.2.2 Applying ODC to MRC

The first step is to apply MRC on the ODC base. The same charge is applied to all route options of a given flight between an origin and destination. As ODC has a positive effect on traffic in respect to CO_2 emissions, but it does not take airspace capacity constraints into account.

The second step is therefore to apply MRC, along the principles explained above. The modulation of charges - expressed as a factor M, defined per route, that reduces or increases the total route charge of that specific route – generates an incentive to fly more fuel-efficient routes, and avoid congested areas/time periods.

The route charge is calculated in a similar way as with the original MRC concept:

$$RC = ODC * M, \;\; where \;\; M_L < M < M_H$$

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ODC: baseline route charge according to ODC

ODC and MRC can be applied to the example in Figure 4. Due to the application of ODC the base route charge for all three route options F1, F2 and F3 is equal to the ODC route charge. If there are no constraints, and the charge for all three options is equal to ODC the shortest route will be chosen. In this case it would be F2. But if the demand is too high on the sectors F1/F2 are passing through, the modulation factor M for F1 and F2 can be adjusted to make these route options less attractive compared to F3.

3.3.2.3 Full GRC Solution

For the Full GRC Solution, the consortium will investigate how the current advances in the measurement and assessment of the climate impact could be used to propose a future, environmentally friendly route charging system.

Algorithmic climate change functions (aCCFs) that were developed in the FlyATM4E project, offer detailed spatial and temporal information on the impact of aviation on future near-surface temperature changes. The aCCFs can be computed using meteorological input data derived from sources such as numerical weather prediction models, like ERA5.

The CLIMaCCF V1.0 Python library will be used for computing individual and merged non-CO_2 algorithmic climate change functions [27]. The library is a product of work performed in FlyATM 4E and ALARM projects. The underlying models are still under development and validation.

Very preliminary idea would be a mechanism that would “reward” avoidance of climate sensitive areas, while still leaving the flexibility of using the said areas, maybe for a higher fee.

Figure 5. Example of climate hotspot and different trajectory possibilities.

In order to formulate this Solution, Green-GEAR will launch a stated preference (SP) survey aimed at assessing the AUs' willingness-to-pay (WTP) for the reduction of climate impacts, taking into account flight operational characteristics. Climate hotspots and the willingness-to-pay of different airline types will be used in the modelling to assess the feasibility and potential benefits of the full GRC Solution[6].

3.3.2.4 Use cases

The use cases relevant to describe how the Solution impacts the business and strategic operations planning activities of the stakeholders involved. The process starts with the collection of the information necessary to feed the system that determines the new route charges mechanism. It ends with the AU's decision to file a flight plan that takes into account the new route charges.

The three options/mechanisms each represent a use case. The stakeholders are the same across the three use cases, and share even the most of the actions. The main changes are presented through the new stakeholder – Central Planner. The Central Planner encompasses the new functions, in each of the use case. These new functionalities are the subject of the assessments in the Green-GEAR project, while the functions of other stakeholders are here for having the complete picture on the overall processes, not to be assessed per se.

The MRC use case is depicted in Figure 6, the ODC+MRC in Figure 7 and Full GRC Solution in Figure 8. The text below describes the roles and functions of various stakeholders, the variations across the use cases are described, where such differences exist.

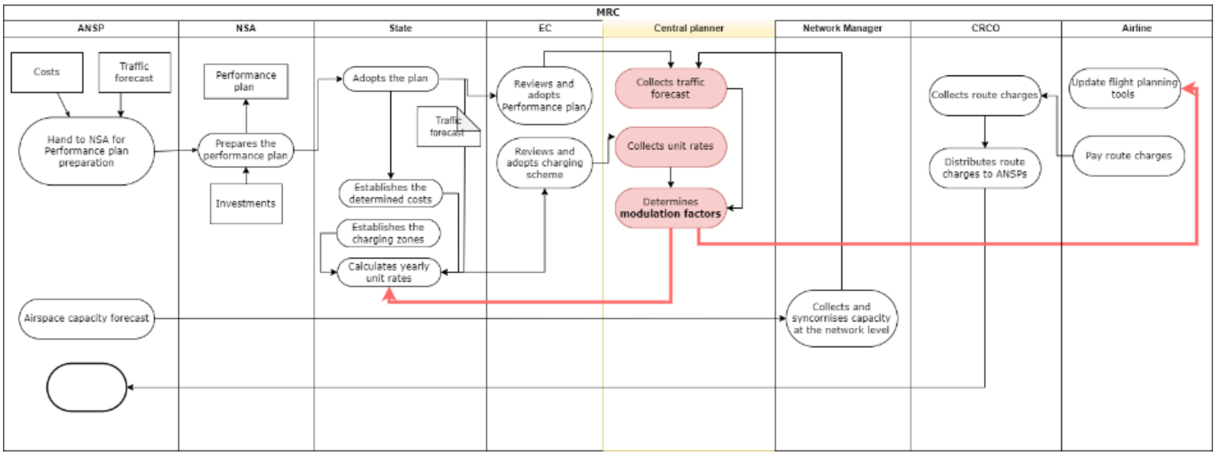

Figure 6. MRC use case.

European Commission and States. The EC and the States will have an essential role in the establishment of the route charging mechanism and its oversight. This will require the revision of the SES performance & charging scheme. For the EC, this means inter alia conducting the regulatory impact assessment of the new charging mechanism, evaluating if this incentive scheme is "effective and

[6] The details of the Full GRC Solution will be presented in the final OSED, here we describe the Solution at a high-level.

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setting parameters in a non-discriminatory and transparent manner". This also includes setting up the corresponding stakeholder consultation arrangements and submitting the new text to the co-legislators in view of the adoption. For the States, represented by their NSA, this means conducting an impact assessment at national level, organising the corresponding stakeholder consultations, and agreeing with their peers on a coordinated implementation EU-wide.

After the new charging scheme is adopted, the EC and the States will also have to conduct additional activities that are specific to the chosen option:

- MRC: When establishing their performance plan, ahead of a new reference period, the NSA will have to include yearly unit rates that are calculated by applying on the actual trajectories, the modulation of charges factors generated by the Central Planner. The plan will include a justification of the impact of these modulation factors on the ANSP revenues, and on the ability of the ANSP to deliver the air navigation services with the expected performance levels (e.g. capacity). The EC, when approving the cost efficiency performance targets submitted by the State, will validate that the impact of the modulation of charges incentive is correctly reflected into these targets. When reporting on the yearly application of the performance and charging scheme, the NSA will need to exercise a specific scrutiny on the impact of the application of the new charging mechanisms, e.g. by comparing it to the previous charging system. The EC may have to exercise the same level of scrutiny when assessing the yearly implementation of the performance and charging scheme (by validating that the modulation of charges incentive is correctly reflected into the actual unit rates and actual charges incurred by airspace users).
- ODC+MRC: The tasks involved by the ODC+MRC charging option are the same as for the ODC option, with one difference. The ODC charge needs to be synchronised between the impacted States/NSAs, and they may have to implement an additional level of scrutiny to validate that the ODC does not generate unwanted distortions at individual ANSP and airline level (e.g. to respect the revenue neutrality principle).
- Full GRC application: In addition to the tasks described above, the EC and the NSA may have to: Before the implementation of such a mechanism, assess and validate the mechanism that will underpin the GRC, for calculating the combined climate impacts of CO_2 and non- CO_2 emissions, based on scientific evidence and testing in operational conditions,

NSAs and the PRB. NSAs and the PRB must integrate the modulation of charges mechanism in their works when determining – and assessing, respectively – unit rates and performance targets. They also need to be involved in the post-operations analysis of the MRC (or ODC+MRC) mechanism, its impact on flight efficiency and ANS capacity, in particular during the transition period when stakeholder consultation will be critical to ensure proper implementation.

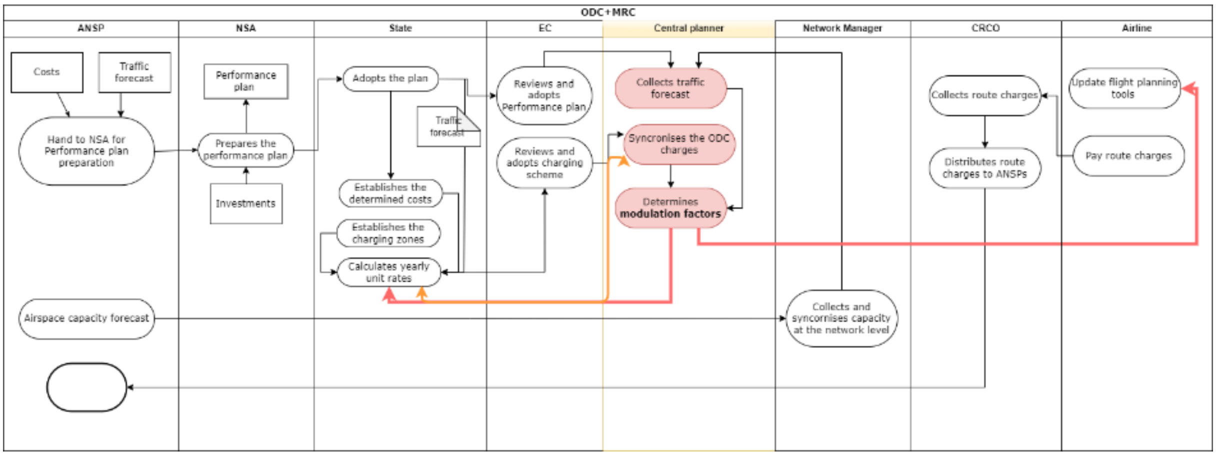

Figure 7. ODC+MRC use case.

Central Planner, is a new stakeholder/function. On a yearly basis, the Central planner collects information to forecast the demand and the expected operational network situation of year N+1: traffic forecasts with modelling of flight distribution across the ANSPs, capacity plans at ANSP level (declared capacity) and identification of congestion areas. It is assumed that this process would build on the NOP planning process that is already in place and collects similar information from established ANSP contact points. The Central Planner also coordinates yearly with EUROCONTROL/CRCO to collect the service units reported by the NSAs and approved by the EC.

The Central Planner feeds the MRC/ODC+MRC modelling system with these yearly updated figures (traffic forecast, capacity forecast, actual charges), see Figure 6 and Figure 7. From there and from historical traffic, the model simulates the interactions between the actors involved in the airspace considered, and calculates the modulation factors (M), that are shared and coordinated with the States to be included into the charging scheme. The approved charging scheme is then shared with the AUs.

In case of the Full GRC Solution, a common climate hotspot forecast (see Figure 8) would be needed so that all the stakeholders can have the same information for planning and charging. The exact from of the mechanism is still under investigation, and will be reported in D5.5.

Airlines. With the MRC and ODC+MRC mechanisms, airlines receive an early price signal alerting on risks of congestion/delay. The modulations need to be incorporated in their flight planning tools.

CRCO. Overall, for the MRC and MRC+ODC, the mandate/activities of the CRCO remain unchanged: calculation and collection of routes charges and transfer of the charges collected from the AU by redistributing them to the ANSPs.

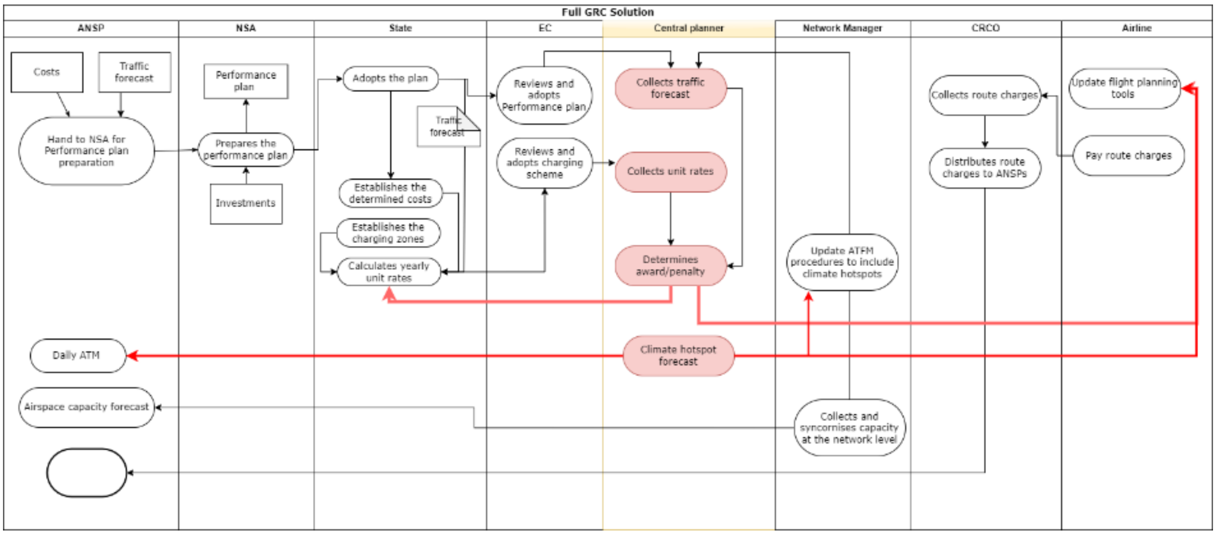

Figure 8. Full GRC use case.

ANSPs and Network Manager. The ANSPs and the Network Manager cooperate with the Central Planner to maximise the accuracy of the capacity forecast.

In case of the Full GRC Solution there might be a need for the Network Management functions to incorporate the avoidance of climate sensitive areas into the Collaborative Decision Management (CDM) operational processes. This includes the adaptation of the role of the Network Manager to the application of the avoidance of climate sensitive areas.

3.3.3 Differences between new and previous operating methods

Activities (in the SESAR architecture) that are impacted by the SESAR solution	Current operating method	New operating method
Planning & oversight of performance and charging (by EC & States)	In line with the tasks described in the Performance and Charging Scheme	Include a step for the validation of the Modulation of charges mechanisms, both at planning and oversight level
Central determination of modulation of Charges (by Central Planner)	Does not exist today. Modulation of charges is allowed at State/Charging Zone level but does not take place in practice	The Central Planner defines the Modulation of Charges values to be applied at route level at strategic planning stage.
Collection and disbursement of en-route charges	In line with the 'EUROCONTROL Principles for Establishing the Cost-Base for En-Route Charges and the Calculation of the Unit	Incorporates tasks to support the Central Planner for the simulation of the Modulation of Charges values and to support

	Rates' and the Performance and Charging Scheme	the NSAs in the determination of the resulting Unit Rates
Strategic and tactical planning of AU operations	Flight Schedule Planner, Airline Operations and Control Centre (AOCC) plan and operate flight	Incorporates the Modulation of Charges into their price model and their FMS. Adapts flight planning decisions accordingly (schedule, trajectory)
Network Operations / ATFCM	ATFCM is responsible for the demand and capacity balancing activities.	Supports the Central Planner in the capacity and demand forecast, which may involve a reinforcement of the current ATFCM processes
MET services	*Provide scope of weather data relevant to the ATM stakeholders **Noting that these services may also be delivered by another player*	Extend services to the forecast of climate hotspots in strategic phase and their detection in pre-tactical/tactical phases (only applicable to the GRC Full Solution)

Table 5: Differences between the new and the previous operating method

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4 Key assumptions

4.1 Operational assumptions

The **GRC Initial Solution**, being a relatively simple change in the route charging mechanism will not have a direct impact on daily operations. The indirect impact could be seen in a traffic redistribution following the changes in the route charge amounts – i.e., the change in price can change the choice of specific trajectory when cost minimisation is used for flight planning.

The **GRC Full Solution** might have an impact on the operations, in following terms:

- As it is based on awarding the avoidance of climate hotspots, which depend on the changing state-of-the atmosphere, the traffic flow changes might become rather dynamic. This could prove to be difficult to manage, as the forecast window would be less than a day (as weather forecasts need to be used for climate hotspot identification). This aspect will be only partially addressed at this TRL level, mainly checking if its introduction at the network level would be feasible at all.

- All stakeholders (e.g., controllers, AUs, NM) would need to have the same baseline information on the climate hotspot prediction, to be able to predict the place and time of worse areas, and thus the forecast of possible traffic re-distribution.

4.2 Performance assumptions

The GRC Solution impacts the following key performance areas (KPAs) [1]:

- Capacity. As determination of modulation of route charges takes into account the airspace and airport capacities, it is expected that the demand capacity imbalances will decrease. This will be assessed through validation exercises.

- Cost efficiency. The direct impact will be on the amount of route charges per flight, a part of operational costs. The exact impact (decrease or increase) will be assessed through the validation exercises. Furthermore, the modulation of route charges must be compliant with the revenue neutrality principle, i.e., each ANSP receives the same income for the same amount of workload. Basically, following the current SES performance and charging scheme guidelines.

- Operational efficiency. The **Initial Solution** options are designed to reduce the CO_2 emissions, mainly through the distance reduction. As the distance is proportional to the fuel consumption, which in turn is proportional to CO_2 emissions, we expect to decrease the fuel consumption (which will be assessed). On the contrary, the **Full GRC Solution** might cause the increase in the fuel consumption, stemming from the climate hotspot avoidance, as the main objective is the reduction of the total climate impact, not only the CO_2 part. This aspect will be assessed in the validations.

- Environment. The **Initial Solution** options are designed to reduce the CO_2 emissions, and we expect to see the reduction in that key performance indicator. The **Full GRC Solution** will not reduce the CO_2 emissions, as it is designed to avoid the portions of airspace that can create the high climate impact (minimising the impact of the joint impact of both CO_2 and non-CO_2 effects). There is a need to assess the total climate impact (both CO_2 and non-CO_2) at the network level, for which there is currently no commonly accepted indicator. The Solution will assess what is possible and what still needs to be researched and developed further.

4.3 Safety assumptions

The GRC Solution do not impact safety as they are geared towards the strategic planning changes. Only the Full GRC Solution might impact tactical operations, in terms of route choice only. The rest of the operational management is assumed to remain the same as today.

4.4 Regulatory assumptions

The **Initial Solution** options will have an impact, likely minimal, on the current regulatory set-up around route charges, as listed in section 3.2.4.

The **Full GRC Solution**, if proven feasible, would require a substantial change to the current regulatory setting. The consortium will assess the requirements and needs and provide recommendations regarding the needed changes.

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5 References

5.1 Applicable documents

This OSED complies with the requirements set out in the following documents:

Content integration

[1] 'DES Performance Framework, Edition 00.01.04'. Jun. 29, 2023.

[2] 'DES Common Assumptions, Edition 00.02.01'. Jun. 29, 2023.

[3] Content Integration, 'Executive Overview, Edition 00.01', Feb. 2023.

[4] 'DES Performance Framework – U-space Companion Document, Edition 00.01.02', Apr. 2023.

Content development

[5] SESAR 3 Joint Undertaking, 'Communication Guidelines 2022-2027, Edition 0.03', Nov. 2022.

System and service development

Performance management

[6] 'Performance Assessment and Gap Analysis Report (PAGAR) 2019 – updated version, Edition 00.01.00'. May 20, 2021.

[7] 'SESAR Solution Cost Benefit Analysis (CBA) Quick Start Guide (1_0).docx'.

[8] 'SESAR ECO-EVAL Quick Start Guide (1_0).docx'.

[9] 'Performance Assessment and Gap Analysis Report (2019), Edition 00.01.02'. Dec. 13, 2019.

Validation

[10] 'DES HE requirements and validation /demonstration guidelines, Edition 3.00'. Sep. 15, 2023.

[11] 'DES SESAR Maturity Criteria and sub-Criteria_01_01 (1_1).xls'.

System engineering

Safety

[12] 'DES expanded safety reference material (E-SRM), Edition 1.2'. Nov. 17, 2023.

[13] 'Guideline to Applying the Extended Safety Reference Material (E-SRM), Edition 1.1'. Nov. 17, 2023.

Human performance

[14] 'SESAR DES Human Performance Assessment Process TRL0-TRL8, Edition 00.03.01'. [Online]. Available: November 2022.

Environment assessment

[15] 'SESAR Environment Assessment Process, Edition 04.00.00'. Sep. 23, 2019.

Security

Project and programme management

[16] 'Green-GEAR Grant Agreement No. 101114789, version 1'. May 11, 2023.

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Appendix A Stakeholder identification and benefit impact mechanisms (BIM)

A.1 Stakeholders identification and expectations

Stakeholder	Involvement	Why it matters to the stakeholder
Airline	Planning and operating flights, and paying route charges for ANS services. The GRC Solution should make flight planning more environmentally friendly, through the pricing mechanisms, which should be easily integrated into flight planning software.	The airlines strive to reduce the operating costs, of which the route charges are a part. There are couple of reasons that any change to the route charging is always under scrutiny: • Any increase represents increase in costs, • Any increase in costs should be accompanied by increase in the quality of ANS services, as mandated by performance and charging scheme, and expected by the airlines, • Every change is subject to scrutiny to avoid the possibility of double charging. Reducing environmental impact is important to airlines, as is the reduction of ATFM delays, a portion of which might be reduced through the modulation of charges (initial Solution). Further, the full GRC will look into reduction of the total climate impact, that is rather higher than just the CO_2. It is to be seen if and how the reduction of total climate impact could be set up, and if the benefits are indeed higher than trade-offs.
ANSP	Provision of ANS services on daily bases, staff planning, planning and implementation of investments to better the service provision, traffic forecast, proposal of performance and charging plans.	The ANSPs are paid through the collection of charges, which cover the costs of staff, and investments, aimed at provision of ANS. Any route charging scheme needs to provide enough revenue to cover costs planned in every year of the RP. The safety is primary ANSP concern, but they are also committed to the reduction of environmental impact of aviation. Modulation of route charges (initial Solution) could reduce congestion in certain portions of airspace.

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		The climate hotspot avoidance could make ANS more complex than it is today, as it might divert traffic flows in unexpected ways.
State	Adopts the performance and charging scheme and presents it to the EC.	The performance and charging schemes are regulated and the States are actors in this process. The importance of the charging scheme lies in recovering funds for the ANS provision. If that can be done in such a way that the environmental impact is reduced, even better.
CRCO	Collects route charges from airlines, and redistributes the revenue to the ANSPs. The current process is subject to the performance and charging scheme regulation and Multilateral agreement.	In case the route charging mechanism changes, the process (subject to regulations and agreements) will need to be updated, to redefine the CRCO responsibilities – i.e., detail how the process changes and what it means for CRCO functions.
NM	NM optimise traffic flows by constantly balancing capacity supply and demand while ensuring the safe and efficient operation of flights going to and over Europe	A different route charging mechanism could change the traffic flows. MRC and MRC+ODC are designed to take the capacity into account when setting the modulation charges, which could diminish a part of the capacity related ATFM regulations. The impact of the Full GRC would probably have more impact as it is harder to predict the state of the atmosphere.
Central planner	The GRC Solution would require a set-up of such a function, which could be assigned to one of the stakeholders, it is not necessary to be standalone stakeholder.	The central planner would collect the traffic and capacity forecasts, and unit rates and run the GRC model/s to determine the modulation factors M. The Full GRC Solution will require the central planner to share the state-of-atmosphere forecast and collect the post-operational data for route charges assessment.
Society	Society creates environmental impact	The reduced climate impact from aviation brings benefits to the society.

	through their travel behaviour.	

Table 6: stakeholders' expectations and involvement.

A.2 Benefits impact mechanisms (BIM)

This section contains initial benefits impact mechanisms identified for the GRC Solution options. The final OSED will be contain final benefits mechanism after the validation exercises results are taken into consideration.

The Figure 9 depicts the benefits mechanisms identified for Initial GRC Solution options. Both mechanisms would impact the AUs' route choice, which, in the price signal contains the capacity considerations, and the need for the revenue neutrality.

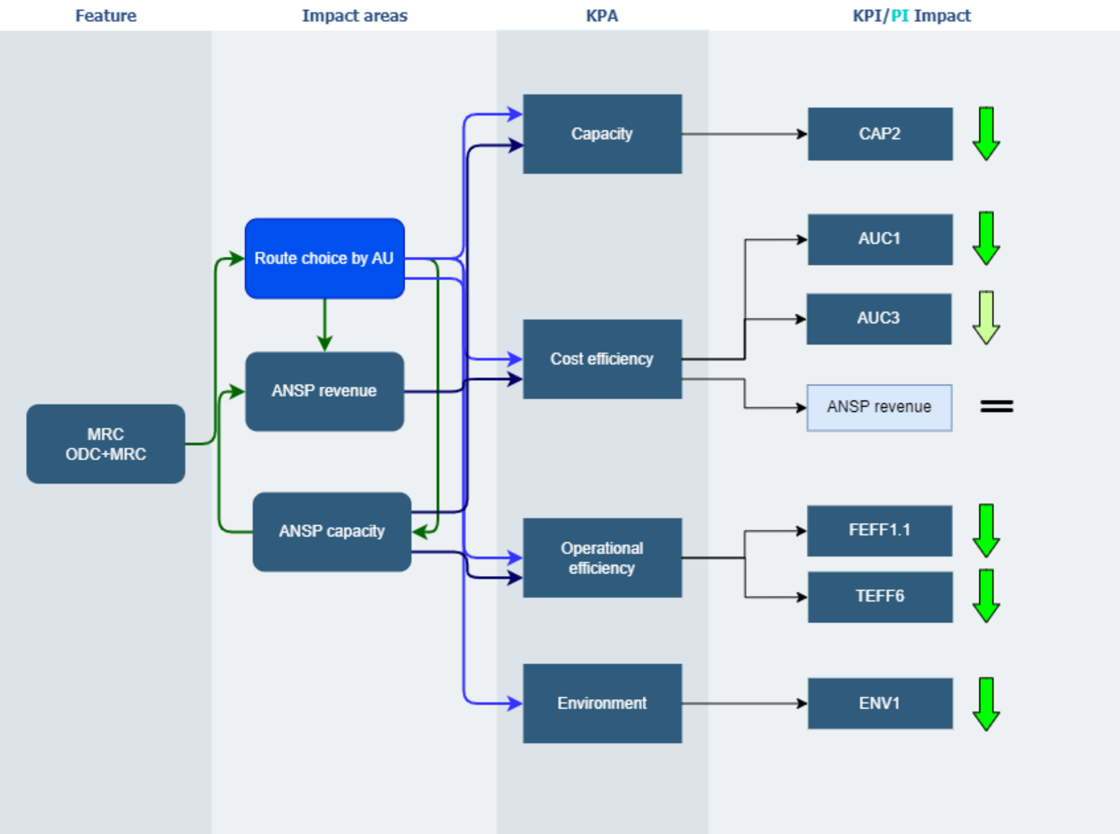

Figure 9. Benefits impact mechanism for MRC and ODC+MRC.

By capacity being taken into account in the route charge (i.e. price) setting, the expectation is that the number of flights planned to cross a certain sector in a certain time period would be aligned with its capacity. The KPI to be used in the assessment is *CAP2 The total number (and percentage) of movements per volume of En-Route airspace per hour for specific traffic mix and density (Very High, High and Medium Complexity) at peak demand hours* [13]. As the expectation is that the price signal takes into account the capacity availability, it is expected that the number of flights planned to cross the sectors at specific time periods will be lower than today. The expectation is that the CAP2 will be lower than today (as measured), which does not mean that the capacity will be lower, but that the demand will be in line with the declared capacity.

The cost efficiency to be measured will be on the direct costs to AUs (i.e. fuel and route charges), as the mechanisms are designed to minimise the distance, and as such the fuel and route charges. Furthermore, the modulation of route charges must be compliant with the revenue neutrality principle, i.e., each ANSP receives the same income for the same amount of workload.

Operational efficiency. The **Initial Solution** options are designed to reduce the CO_2 emissions, mainly through the distance reduction. As the distance is proportional to the fuel consumption, which in turn is proportional to CO_2 emissions, we expect to decrease the fuel consumption (which will be assessed).

As the **Initial Solution** options are designed to reduce the CO_2 emissions, and we expect to see the reduction in that key performance indicator.

The Figure 10 depicts the very first draft benefits mechanisms identified for Full GRC Solution options. This mechanism will likely have very dynamic impact on operations, and at the moment it is not clear what would the impact of changing traffic flows to avoid climate hotspots be on the capacity, which is the subject of validations. The dynamicity is also the reason behind not being able to identify the direction of the changes in the cost efficiency area, prior to the validation exercises.

Regarding the operational efficiency the Full GRC Solution might cause the increase in the fuel consumption, stemming from the climate hotspot avoidance, as the main objective is the reduction of the total climate impact, not only the CO_2 part. This aspect will be assessed in the validations.

The similar is expected in the environment KPA. It is likely that the Full GRC Solution will not reduce the CO_2 emissions, as it is designed to avoid the portions of airspace that can create the high climate impact (minimising the impact of the joint impact of both CO_2 and non-CO_2 effects). There is a need to assess the total climate impact (both CO_2 and non-CO_2) at the network level, for which there is currently no commonly accepted indicator. The Solution will assess what is possible and what still needs to be researched and developed further.

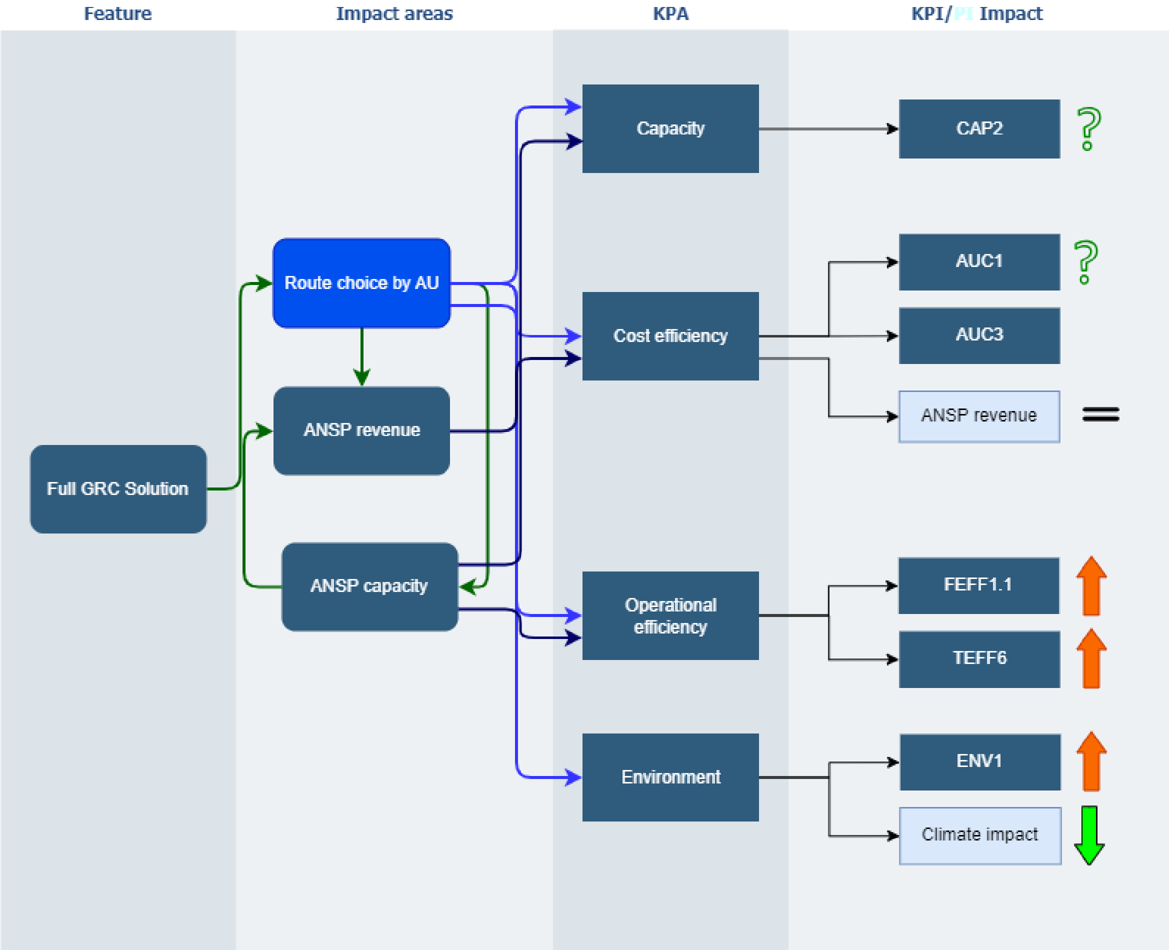

Figure 10. Full GRC Solution benefits mechanism draft.

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