WGMM

Working Group on Monitoring Methodologies of CO_2 Neutral Fuels

2025

SUMMARY OF TECHNOLOGY ASSESSMENTS

Introduction

This publication, which summarises the eleven technology options assessed in our full report "Monitoring the Use of CO_2 Neutral Fuels in Road Transport – A Cross-Sectoral Industry Assessment", aims to provide policymakers, technical experts, and stakeholders with a concise though comprehensive overview of the identified technology options considered for monitoring and proving that ICE vehicles placed on the EU market post-2035 fuelled with CO_2 neutral fuels (CNFs) are effectively using these fuels.

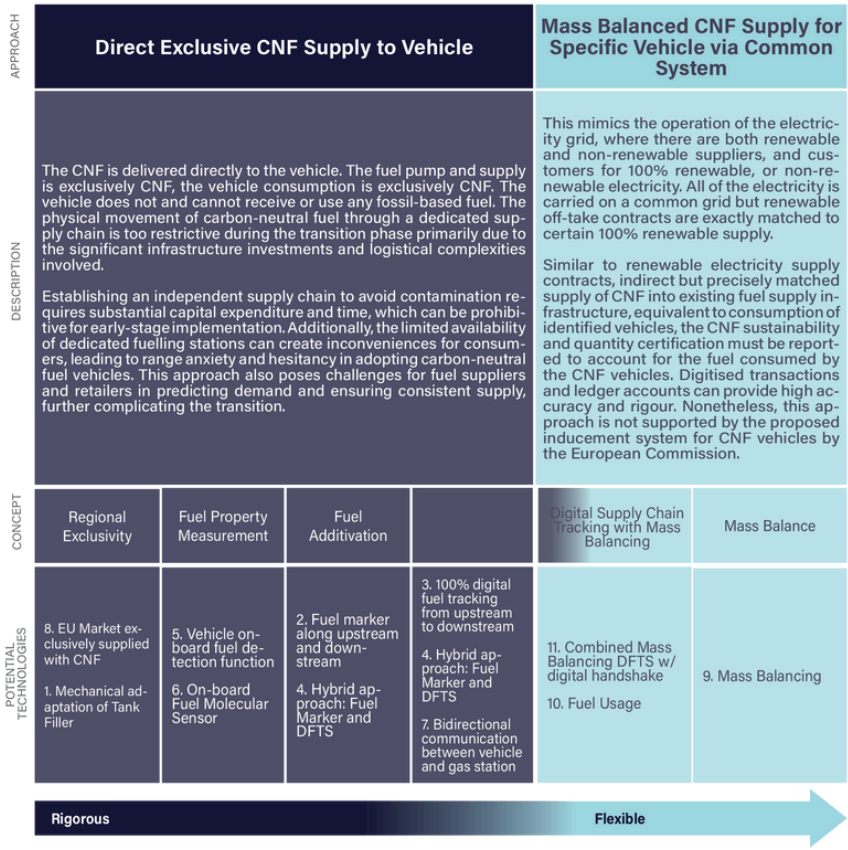
These options are not recommendations; rather, they represent the technical spectrum of approaches identified and evaluated by over 160 experts from more than 50 global organisations within the Working Group on Monitoring Methodologies (WGMM).

Each of the 11 monitoring methodologies is presented in a standardised format, including a description of the concept and detection method (Chapter 5), an assessment of implications for customers and the fuel retail sector (Chapter 6), and an evaluation of potential regulatory requirements (Chapter 7). The options range from physical approaches such as dedicated infrastructure or mechanical adaptations, to digital solutions including fuel tracking systems, bidirectional communication, and hybrid concepts. Indirect systems like mass-balancing and certificate-based tracking are also explored.

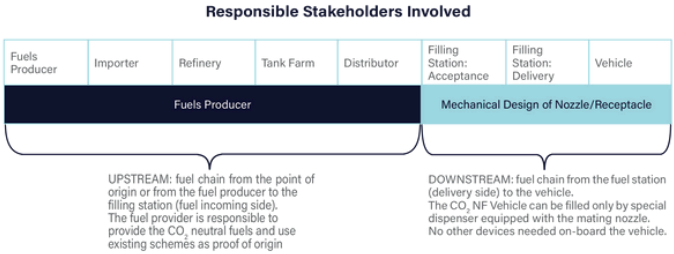
Crucially, these methodologies were reviewed not only for their technical robustness but also for their feasibility in the context of consumer behaviour, retail compatibility, and future-proof regulatory design. Attention was paid to inducement mechanisms that can enforce the exclusive use of CNFs and address challenges such as tampering, cross-border vehicle use, and infrastructure adaptation.

The WGMM process has followed strict neutrality and legal compliance, with all work accompanied by external antitrust oversight. This publication is part of our broader effort to inform and support the legislative process with objective, cross-sectoral insight into CNF monitoring solutions. We trust that this summary contributes meaningfully to the Commission's and Member States experts' deliberations on implementing a credible framework for CO_2 neutral vehicles after 2035.

Summary of the Eleven Monitoring Options



Option 1 – Mechanical Adaption of tank Filler / Nozzle



Description of Technology

The mechanical adaptation of the tank filler/nozzle ensures a dedicated connection between the filling station and the vehicle, preventing misfuelling by using specific nozzles that are incompatible with fossil fuel receptacles. However, for a complete monitoring system, this method must be paired with an upstream verification process to ensure the correct fuel reaches the station, is stored properly, and is dispensed correctly (like for example a certification scheme). The system varies based on fuel type. For liquid fuels, such as Diesel and gasoline- standardised nozzle spouts with different diameters are used. For gaseous fuels, where a leakproof connection is required, specific interface connector geometries are standardised for the different gas types (e.g. CNG, LPG, H2). While effective in preventing misfuelling, this approach has challenges, including the need for duplicate nozzles in the fuel stations during the transition phase, vehicle dependency on CO2-neutral fuel availability, and the potential for tampering, which current mechanical designs cannot fully eliminate.

Customer & Retail Perspectives

Advantages:

- Implementation is straightforward and widely accepted if the current nozzles are compatible and future nozzles follow a similar design. This is only feasible if existing dispensers are usable and future dispensers remain consistent in design.
- Experience with differentiation of existing liquid and gaseous fuels
- Introduction of New Standards
- No need of further onboard monitoring system
- Adaptability of Legacy Fleet by possible retrofit
- Existing Globally Recognized Standards for Liquid and Gas Refuelling receptacles and nozzles
- Simplicity and Accessibility
- Low Total Cost of Ownership
- Global Reliability and Interchangeability
- Environmental Benefits
- Simplicity for All EU-Regions

Disadvantages:

- Adapter Requirement for Non-EU Regions
- Potential for Tampering with Adapters
- Dependence on Nozzle and Receptacle Availability
- Supply chain duplication at the retail stations

Implementation requirements:

- European Agreement on Nozzle Requirements, Diameter, and Shape
- Standardization and Global Compatibility

Regulatory Assessment

This option requires a new standardisation effort for tamper evident fuelling technologies, involving several product standards for the refilling interfaces, related working groups and amendments to Directive 2009/126/EC of the European Parliament and of the Council of 21 October 2009 on Stage II petrol vapour recovery during refuelling of motor vehicles at service stations (required only for liquid fuels such as renewable petrol, because gaseous fuels -bioCNG, bioLNG, bioLPG, biopropane have leak-proof connections). The large number of new standardisations required illustrates the significant effort and time required to implement this monitoring methodology. From a policy perspective, a mechanical solution requiring new nozzles would entail a high administrative burden, significant international coordination efforts and a long implementation period.

Option 2 – Fuel Marker along Upstream and Downstream

Description of Technology

The use of a CNF fuel marker additive, a chemical additive that is added to fuels to make them identifiable, often used to combat fraud, allows market participants to introduce climate-neutral fuel with two safety features: Colour and a chemical identifier tag. Fuel markers help identify CNF liquid fuel products, which are easy to dispense and may include additional labelling. As synthetic fuels are similar to the chemical composition of fossil fuels and have no adverse impact on vehicle emissions. However, this technology is not suitable for gaseous fuels. The system must be combined with a vehicle or gas station sensor to ensure compliance, which is a technically complex task that remains unproven, as detection thresholds still require thorough validation. Moreover, the use of a chemical marker to distinguish CN fuel from conventional fossil fuels introduces additional costs and reduces operational flexibility by necessitating a separate infrastructure.

Customer & Retail Perspectives

Advantages:

- Established and familiar system
- Inducement potential
- No major behavioural changes for consumers
- Minimal infrastructure changes needed
- Enhanced safety and fraud prevention
- Potential for integration with digital tracking and authenticity verification systems
- Low implementation costs
- Flexible monitoring capabilities

Disadvantages:

- Limited usability outside the EU
- Binary compliance detection
- Reduced flexibility in inducement mechanisms
- Compatibility issues with gaseous fuels
- Cost implementation for petrol stations or vehicle depending on placement of sensor
- In-vehicle sensors yet to be proven as detection thresholds still require thorough validation
- Risk of sophisticated counterfeiting or neutralization of the chemical marker by malicious actors

Regulatory Assessment

Implications to fuel regulations and standards must be investigated before implementing colour and chemical identifier tags. Potential changes will require substantial lead time to ensure stability, visibility, safety and environmental compliance. Almost all ISO/EN fuel standards allow use of dyes and markers.

Option 3 – 100% Digital Fuel Tracking System from Upstream to Downstream (DFTS w/ Digital Handshake)

Description of Technology

Digital twins (DFTS) are already used in other industrial systems, and their application in fuels offers secure digital tracking and ledger accounting of CO_2-neutral fuel (CNF) across the fuel supply system and in-vehicle operation. DFTS allows fast onboarding by utilizing existing data from the RED II framework in fuel supply infrastructure and vehicles. It digitalizes the entire fuel supply chain, from production to the end consumer, enabling stakeholders to utilize CNF as a new fuel variant with digital certification. DFTS tracks CO_2 and certifies sustainability reports along the supply chain, pairing the vehicle with the fuel supply through a digital handshake. It also incorporates a fuelling monitor in the vehicle, confirms CNF use for CNF-only vehicles, and ensures robustness with plausibility checks. DFTS provides end-to-end fuel tracking, transparency in sustainability, and the ability for inducement reactions if CNF is not detected. It also allows authorities to access consumer data and enables flexible responses in emergency situations.

Customer & Retail Perspectives

Advantages:

- Technology availability and fast implementation
- Cost efficiency
- Ease of use and high customer acceptance
- Data security and compliance
- Enhanced monitoring (extended information transfer beyond simple yes/no information is possible) and flexibility mechanisms
- Regulatory geofencing capability
- Future-ready and scalable applications
- Enables real-time emissions auditing and compliance reporting for fleet operators and regulators

Disadvantages:

- Special attention regarding vulnerability to data latency and transmission failures necessary.
- Increasing effort to reduce susceptibility to system failures by multi trust centre approach
- Data privacy and GDPR compliance as for all digital systems demands special care
- Limitations in EU's external border fuelling flexibility if implemented without regulatory geofencing
- Limited infrastructure availability initially
- Dependence on continuous internet connectivity may create accessibility issues in remote or underserved regions

Implementation requirements:

- Reliable datalink between stations and central host
- Qualified filling stations
- Legislative definition of penalty enforcement

Regulatory Assessment

The Cyber Resilience Act (CRA) and the NIS2 Directive apply to the cyber security of data along the value chain (data, storage, back-end). NIS2 Annex I "High Criticality Sectors, 1.) Energy"; may need to be amended to include a new category "Renewable Fuels" in addition to the existing categories of oil, gas and hydrogen. Regarding the cybersecurity of in-vehicle data, Regulation (EU) 2024/1257 requires vehicle manufacturers to ensure the secure transmission of emissions-related data by implementing cybersecurity measures in accordance with UN R155. UN R155 refers to ISO/SAE 21434 and takes a risk-based approach. It requires the OEM to implement and process a risk assessment as part of a Cyber Security Management System (CSMS). UN R156 regulates software updates and Software Update Management Systems (SUMS). From a vehicle type-approval perspective, Regulation (EU) 2024/1257 should be amended to extend rules on data access, data communication and data protection against misuse and manipulation to DFTS-relevant data. Fuel-related data should be made available to vehicle users in a similar way to environmental data. The planned new implementing regulation of Regulation (EU) 2024/1257 for the type-approval of CNF vehicles must remain technology-neutral in order to allow for the possibility of monitoring the use of CNF by means of a digital device capable of communicating with the refuelling station (DFTS). The implementing regulation should describe an appropriate trigger system that would be activated in case of non-CNF refuelling.

Option 4 – Hybrid Approach: Upstream: Fuel Marker & Sensor until EU Border Filling Station/ Downstream: Digital Fuel Tracking System (DFTS) with Digital Handshake

Description of Technology

The "Triple Solution" enables market participants (from fuel industries to vehicle manufacturers) to introduce CO2-Neutral Fuel by combining two safety features and a digital solution. The physical features, are colour and a chemical tag. This marking system includes CO_2 tracking and certification for CO_2 neutral fuel along the supply chain, from the fuel depot to the filling station, and a digital refuelling monitor in the vehicle. The vehicle performs a digital handshake with the petrol station to confirm the refuelling event. If the fuel is not CNF, the vehicle reacts accordingly. The Hybrid Approach connects all relevant stakeholders, including the customs directorate and Ministries of Finance, for CNF confirmation, plausibility checks, and tracking of fuel and CO_2 footprint. It is important to note that this technology is unsuitable for gaseous fuels.

Customer & Retail Perspectives

Advantages:

Upstream (Fuel Marker System):

- Established and familiar system
- Inducement potential
- No major behavioural changes for consumers
- Minimal infrastructure changes needed
- Enhanced safety and fraud prevention
- Potential for integration with digital tracking and authenticity verification systems
- Low implementation costs
- Flexible monitoring capabilities

Downstream (Digital Fuel Tracking System):

- Technology availability and fast implementation
- Cost efficiency
- Ease of use and high customer acceptance
- Data security and compliance
- Enhanced monitoring (extended information transfer beyond simple yes/no information is possible) and flexibility mechanisms
- Regulatory geofencing capability
- Future-ready and scalable applications
- Enables real-time emissions auditing and compliance reporting for fleet operators and regulators

Disadvantages:

Upstream (Fuel Marker System):

- Limited usability outside the EU
- Binary compliance detection
- Reduced flexibility in inducement mechanisms
- Compatibility issues with gaseous fuels
- Cost implementation for petrol stations or vehicle depending on placement of sensor
- In-vehicle sensors yet to be proven as detection thresholds still require thorough validation
- Risk of sophisticated counterfeiting or neutralization of the chemical marker by malicious actors

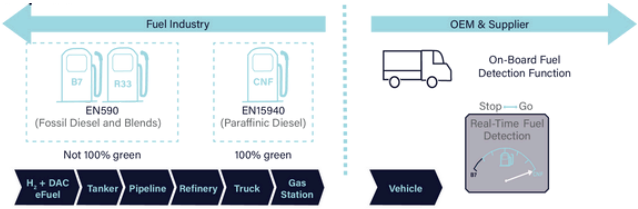
Downstream (Digital Fuel Tracking System):

- Special attention regarding vulnerability to data latency and transmission failures necessary
- Increasing effort to reduce susceptibility to system failures by multi trust centre approach
- Data privacy and GDPR compliance as for all digital systems demands special care
- Limitations in EU's external border fuelling flexibility if implemented without regulatory geofencing
- Limited infrastructure availability initially
- Dependence on continuous internet connectivity may create accessibility issues in remote or underserved regions

Regulatory Assessment

Upstream part: Fuel Marker (as described in option 2), Downstream part: Digital Fuel Tracking System (as described in option 3). As with the digital handshake-only option, preventing fraud at field level remains a challenge, due to the lack of automated, tamper-proof verification mechanisms in real time.

Option 5 – On-Board Fuel Detection Function



Description of Technology

A fuel detection function could be implemented based on the existing vehicle and engine system technology without new sensors or interfaces. It is based on the difference in physical properties between regular, fossil fuels and future, Carbon-Neutral Fuels (CNF). With this function, it is also possible to alter engine operation when a non-carbon-neutral fuel is used. Several levels of alteration could be considered, from warning the driver to limiting or stopping vehicle operation, similar to those used in modern diesel cars/vans/trucks with SCR technology to control NOx emissions. It could be implemented without requiring further data connections or services in a data cloud. This would protect the owner's data privacy while being resilient against cyber-attacks, IT fraud and tampering. This detection function could be easily integrated in new vehicles or even be implemented on existing vehicles in the market. The low complexity of a detection function allows for a fast realization and effective implementation in a vehicle, without modifications to the current infrastructure. In cases where CNF is chemically identical to fossil fuel, e.g. HVO, MtG, Compressed Natural Gas (CNG), LPG, the proposed detection methodology may be limited.

Customer & Retail Perspectives

Advantages:

- Enhanced fuel security [AL1]
- Cost-efficiency and fast implementation
- Privacy and security protection
- Compatibility with legacy fleet

Disadvantages:

- Restricted cross-border functionality
- Incompatibility with gaseous fuels
- Operational risks with sensor malfunction
- In-vehicle sensors yet to be proven as detection thresholds still require thorough validation

Implementation requirements:

- Early established system that allows for inducement
- Vehicles must detect fuel quantity and misfuelling events, and be able to monitor and report it through software
- Additional regulatory geofencing software for outside the EU
- Established test procedures for inspections (measurement per fuel)

Regulatory Assessment

The vehicle on-board fuel detection function enables the use of CNF in modern vehicles by detecting the correct fuel without significant changes to infrastructure or the vehicle. This solution utilizes existing sensors, making it practical and requiring fewer regulatory changes. There should be a harmonisation of the standards for carbon-neutral diesel and gasoline fuels to ensure that this technology can reliably detect fuel properties, similar to what is currently applied with certified fuels (Diesel EN 590 or Gasoline EN 228). This standard alignment is essential for maintaining vehicle performance and emissions compliance, regardless of the specific carbon-neutral fuel used.

Option 6 – Vehicle On-Board Fuel Molecular Sensor

Description of Technology

Near-Infrared (NIR) spectroscopy is a mature, automotive-grade technology that analyzes thousands of molecular bonds to generate a unique "fuel fingerprint." It enables clear separation between fossil fuels and 100% fossil-free fuels, even when both meet current EU standards (EN590, EN228, EN15940, EN14214, EN15293). The technology has benefited from 15+ years of development with OEMs, engineering teams, and universities. It is already homologated, field-proven, and deployed at scale in the transportation market. While the sensor does not embed geolocation features directly, it can be connected to external geofencing systems and digital certification platforms, enabling full traceability and regulatory compliance throughout the fuel lifecycle. A central element of this solution is the use of a certified CNF molecular database, allowing each analysed fuel sample to be matched with its "fuel digital twin". This digital twin ensures that the fuel's real-time molecular signature corresponds precisely to its certified production origin and declared carbon footprint. This technology is suitable for gaseous fuels but will require extra development.

In order to ensure the reliability, repeatability, and legal compliance of the fuel identification system, the sensor must be installed by a pre-approved technical center following a validated installation protocol (mounting notice). This is aligned with existing regulatory frameworks already in place in Europe.
For instance, in France, similar rules apply to FlexFuel E85 retrofit kits, where installation must be carried out by an approved garage using certified hardware and software to enable an official fuel-type update on the vehicle's carte grise (registration document). This framework has been operational since 2017 for passenger cars (PC), and extended by the CNRV and DREAL to cover light-duty and heavy-duty vehicles (LDV, HDV) for the use of 100% renewable diesel.

This structured installation procedure ensures:

- Secure and tamper-proof sensor deployment,
- Compliance with safety and OBD integration standards,
- Eligibility for tax or regulatory benefits associated with low-carbon fuel use.

It also allows the system to be deployed either as a factory-fitted (OEM) solution or as a certified retrofit, offering flexibility and scalability across the existing vehicle fleet.

Customer & Retail Perspective

Advantages:

- High certainty in fuel type detection
- Fully compatible with existing fuel infrastructure (no changes at petrol stations)
- Security of fuel compliance
- Immediate availability and already homologated in a particular market
- Proven field performance (100M+ km)
- Supports retrofit of existing fleets
- Real-time detection enables partial refuelling and fuel mix tracking
- Increase flexibility for drivers travelling outside the EU

Disadvantages:

- Cost: Higher than basic sensors, but compatible with large-scale automotive production[2]
- Maintenance: No maintenance required in real-world deployments over 3.5 years
- In-vehicle sensors yet to be proven as detection thresholds still require thorough validation.
- Fuel scope: Currently limited to liquid fuels, not applicable to gaseous fuels distributed through gas pipelines.
- Need for an CNF database: Over-the-air-accessible, batch-to-batch certified and up to date

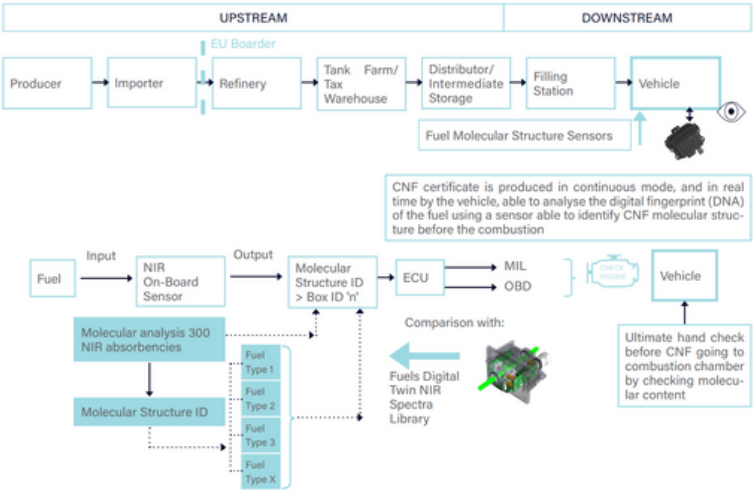
Implementation requirements:

- Early system integration to allow for regulation-based inducement
- Implementation of regulatory geofencing software[4]
- Clearly defined test procedures
- CNF-compliant database monitored by an authority

Regulatory Assessment

Option 6 combines high-resolution molecular detection with the possibility to connect to digital handshake systems option, enabling full traceability from fuel production through distribution to the vehicle's fuel tank. This ensures that the molecular structure of the fuel entering the engine matches the certified product across the supply chain. This end-to-end traceability supports regulatory compliance under CSRD Scope 3 and the Renewable Energy Directive (RED II / RED III) [5]. It also enables identification and certification of emerging synthetic mono-molecular fuels, positioning this technology as a future-ready tool for sustainable fuel policy enforcement and lifecycle accounting.

Option 6 – Vehicle On-Board Fuel Molecular Sensor



Option 7 – Bidirectional Communication between Vehicle and Filling Station

Description of Technology

This solution centres on three key functionalities:

- Implementing Near Field Communication (NFC) between the fuel nozzle and the vehicle's filler neck to guarantee the correct nozzle is utilized throughout the refuelling process, thereby preventing tampering. The NFC system is used to trigger to initiate the OTA communication.
- Establishing bidirectional Over-The-Air (OTA) communication via Bluetooth or Wi-Fi with the CO_2 neutral fuel (CNF) filling station to authenticate the partner and build trust before commencing fuel transfer.
- Implementing a Refill Release Valve (RRV) between filler neck and tank to prevent the vehicle from being refilled with the incorrect fuel.

The combination of these functionalities leads to tamper-proof solution which can be easily combined with other solutions and the principle can be reused at any CNF transition point in the supply chain.

Customer & Retail Perspectives

Advantages:

- Prevention of misfuelling prior to filling (intentional or unintentional)
- Instant alerts for drivers regarding incorrect nozzle usage
- Communication between vehicle and filling station enables additional features
- Supports modular integration with other digital or physical CNF verification systems across the supply chain

Disadvantages:

- Increased costs due to additional hardware
- Susceptibility to data transmission errors
- Data latency concerns
- Dependence on stable connectivity (internet or Wi-Fi) may limit functionality in remote or low-signal areas

Implementation requirements:

- Additional regulatory geofencing functionality to switch off the system outside the EU
- Additional solution to enable voluntary refilling of legacy cars with CNF
- Workaround for emergency refilling (closed RRV)

Regulatory Assessment

- Security & Fraud Resistance: High security with digital certificates required but adds complexity
- Implementation Complexity: Moderate due to required NFC infrastructure and certification
- Fuel Detection Accuracy: Good but lacks fuel composition verification
- Cost of Deployment: Moderate with potential for shared costs
- Real-Time Fuel Validation: Ensures CNF use with cybersecurity compliance
- Flexibility & Scalability: High scalability but needs global/regional standards

Option 8 – EU Market Exclusively Supplied with CNF

Description of Technology

This option explores the potential of a full CO2 neutral fuel (CNF) market after 2035 in EU-27. This option assumes that CNF availability would be sufficient to meet the entire vehicle demand, and therefore CNF is the only available product in the fuel market. This is potentially the result of the new CNF vehicle class. All other monitoring methodologies are just a transition to this option.

Customer & Retail Perspectives

Advantages:

- Full Transition to Sustainable Fuels
- Simplified Fuel Options for Consumers
- Compatibility with Current Infrastructure
- Potential to Use Conventional Fuel Outside the EU
- No Additional Inspection Requirements
- Eliminates long-term compliance and monitoring costs by standardizing fuel supply to CNF only

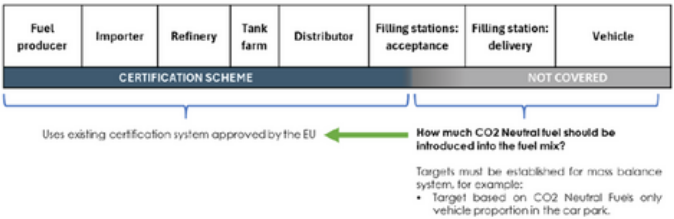
Disadvantages:

- Many decades away for it to happen
- Lack of Incentive During the Transition Phase
- Potential Supply Challenges for Non-EU Travel
- Dependence on Successful CNF Ramp-Up

Regulatory Assessment

The share of renewable energy carriers in the transport sector is regulated in the Renewable Energy Directive (RED). The current goal of the RED III is an energetic share of renewable energy of 29% in 2030, which includes multipliers for different compliance options, or a greenhouse gas (GHG) reduction of 14.5%. Currently, less than 7% CNFs are in the European fuel mix. Targets beyond 2030 are not available and will be discussed in the next review in 2027. EU Member States are currently implementing the RED III. Based on current EU climate goals, the EU wants to achieve -55% GHG emissions in 2030 and is currently debating -90% in 2040. Provided the availability of CNF is dedicated to the supply of all new cars, vans and trucks, this could be a more realistic approach. Once 100% CNF in the European fuel market is achieved, all new vehicles would run exclusively on CNF. If the revision of the RED leads to 100% CNF in the future, it automatically limits the necessity of a CNF monitoring methodologies. Also the ETS2, which includes the road sector, will ensure a clear phase-out of fossil fuels as emission allowances will get more expensive over time. Once an economic break-even in comparison to fossil fuels is achieved, the switch to CNFs can be quite rapid.

Option 9 - Mass-Balanced CNF Supply to Each CNF Vehicle (in accordance with the WGMM 2024 Report)



Description of Technology

Mass balancing is a simple and practical method for tracking CO_2-neutral fuels (CNF) across the supply chain. Its key advantage lies in leveraging the existing fuel infrastructure, eliminating the need for a dedicated CNF-specific system that could otherwise increase challenges to the adoption of CNF vehicles. This approach ensures that the amount of CNF introduced into the market matches the amount consumed, based on certified schemes under the Renewable Energy Directive (RED). Rather than requiring a direct physical link between CNF production and vehicle consumption, mass balancing allows CNF to be added to the general fuel supply system—such as pipelines, terminals, or retail stations—while still meeting the actual demand from CNF vehicles. By decoupling carbon compliance from the physical fuel path, mass balancing enables the immediate use of the entire existing fueling network. This accelerates CNF deployment and ensures that drivers can refuel anywhere without disruption. Vehicle consumption can be estimated using statistical data, such as average mileage/proportion of CNF vehicles registered. The responsibility of such a system can be at customer level e.g. with yearly compensation of the carbon footprint or at vehicle manufacturer level e.g. upfront with the purchase of a new vehicle (e.g., existing Swiss model with upfront compensation leading to immediate environmental benefits). Mass balancing can be implemented either as a transitional solution or as a long-term strategy until CNF is widely available across the EU. A robust and secure accounting system guarantees that vehicle use generates demand exclusively for CNF, delivering the same climate benefits as systems requiring direct physical supply. This system could be enhanced with digital technologies such as fuel tracking platforms, digital handshakes, and two-way communication between vehicles and fueling stations (e.g., Option 10 & 11).

Customer & Retail Perspectives

Advantages:

- European renewable energy mandate is based on this method and it's fully operational and recognized by the EU.
- It leverages existing regulations and infrastructure.
- High flexibility and scalability
- Low-cost barrier to entry
- Positive impact on legacy fleet
- Ease of Implementation and wide network coverage
- Supports gradual market transformation by integrating CNF without disrupting existing fuel supply chains
- Reduced environmental and logistical costs
- Avoids complexity in vehicles
- Industry responsibility over consumer burden
- Successful Implementation in other areas such as green electricity

Disadvantages:

- Absence of fuel usage-based penalties and offsetting if not combined with a digital tracking such as DFTS
- No physical traceability
- Certification and auditing needs
- Risk of fraud and greenwashing if not correctly audited

Regulatory Assessment

From a regulatory perspective, mass balancing is a well-established and highly efficient concept, recognized under several policies. For example, the RED and European Emission Trading System (ETS) are based on mass balancing concepts. A certification scheme along the value chain from the producer to the filling station verifies that all production and sustainability criteria are met. The EU has built the 'Union database for renewable fuels to ensure the traceability of these fuels (more information here). With careful but feasible development, the existing RED mass balancing system could be extended to enable the monitoring of CNF-only vehicles e.g. with using the Shares database. Other countries have already established mass-balancing systems to offset the carbon footprint of new vehicles like Switzerland with a crediting system for eFuels. The existing Commission proposal on a new vehicle class for CNF excludes any mass balancing approach. Therefore, the acceptance of a mass balancing system requires a policy shift, which would need to recognize the degree of security that can be achieved by the available technologies and operational methodologies. Given the efficiencies that are available, a mass balancing concept should not be neglected per se.

Option 10 – Fuel Usage Balancing (FUB)

Description of Technology

FUB tracks every fueling event directly at the individual vehicle level and matches these amounts with certified CNF volumes in the cloud. The reported fueling amounts and corresponding certificates are recorded and voided in a Union-wide Data Base (UDB), ensuring transparency and accountability. If a vehicle falls short of meeting regulatory CNF requirements, the onboard FUB device can trigger a wide range of inducement actions to ensure compliance. This creates a robust, transparent system that guarantees carbon accountability without the need to physically trace individual fuel molecules.

While physical tracking offers conceptual clarity, a mass balancing approach still ensures verifiable carbon neutrality, with a key advantage: it eliminates the need for CNF-specific infrastructure. By decoupling carbon compliance from the physical fuel path, it allows immediate use of the existing fueling network and accelerates CNF adoption. Under this model, responsibility for carbon compliance shifts from vehicle manufacturers to the end-users — the motorists — who purchase CNF certificates corresponding to their fuel consumption. This is a positive paradigm shift: it aligns accountability with control, empowering those who actually consume the fuel to drive demand for carbon-neutral alternatives. The software platform (UDB) enables this by tracking fuel usage, verifying certificate matching, and interacting with the CNF registry to void certificates upon use.

It also lays the foundation for a functioning CNF marketplace, where fuel producers or trading platforms can offer competitively priced CNF and certificates to the motorists. Unlike models that credit manufacturers for upstream CNF production — which lacks a direct link between compliance and actual fuel use — this approach ensures verified emissions reductions by embedding compliance into each fueling event. Manufacturers retain full control over their fleet CO_2 targets by programming vehicles with CNF minimum usage requirements according to their needs.

This creates a new vehicle class — compliant by design — that ties regulatory goals, user responsibility, and fuel sourcing into one system, enabling a functioning, self-reinforcing market for CNF.

Customer & Retail Perspectives

Advantages:

- End-User Focus
- Penalty Indications
- Fuelling History Storage
- Compatibility with Inducement Systems
- Virtual CNF Credits for Sustainability Reporting
- Regulatory Geofencing
- Transparency for Drivers
- Potential for Retrofitting Older Vehicles
- Integration with Connected Services
- Incentives for Early Adoption
- No Need for Fuel Infrastructure Modifications

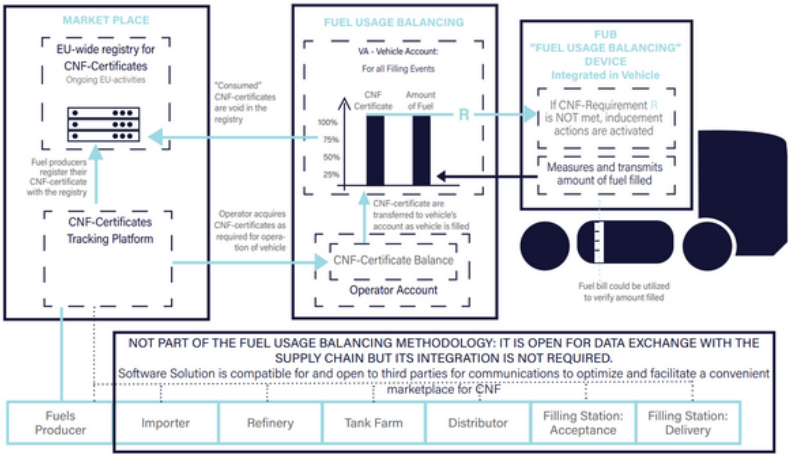
Disadvantages:

- Special attention regarding vulnerability to data latency and transmission failures necessary.
- Increasing effort to reduce susceptibility to system failures by multi trust centre approach
- Data privacy and GDPR compliance as for all digital systems demands special care
- Limitations in EU's external border fuelling flexibility if implemented without regulatory geofencing

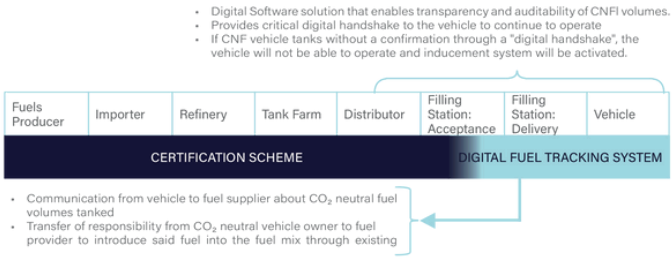
Regulatory Assessment

This method ensures carbon neutrality by monitoring CNF usage through transaction-based tracking rather than physical fuel composition verification. Using life-cycle analysis principles, similar to RED methodology, it focuses on the CO_2 intensity of the fuel used.
Software and cloud services require cybersecurity measures and fraud resistance. New digital protocols and standards might be developed to ensure accuracy and transparency, and an online connection is required for real-time tracking and validation.

Option 10 – Fuel Usage Balancing (FUB)



Option 11 – Combined – Upstream: mass balancing – Downstream: DFTS w/ Digital Handshake)



Description of Technology

This solution enhances Mass-Balancing methodology Option 9 by integrating a digital fuel tracking system. This system ensures that customers required to tank only CO_2 neutral fuels (CNF) transmit their fulfilment obligation through a digital system to the fuel supplier. This is done through a digital solution that safeguards the transparency, robustness, and auditability of the fulfilment obligation. Once the fulfilment obligation is transmitted at the retail station level through a Digital Tracking System to the fuel supplier, the fuel supplier acquires the mandate/obligation to bring the respective amount (Volume) of CNF into the fuel system either at the national or European level depending on how it is defined in the final regulation. This solution allows optimized fulfilment of the CNF obligation after 2035 without requiring extra investment in dedicated supply chains, thus maximizing the existing infrastructure.

The method emphasizes digital tracking to maintain the integrity of CO_2 neutral fuel claims. It ensures vehicles have an inducement system mechanism to monitor CO_2 neutral fuel usage. Customers opting for CO_2 neutral fuels are not guaranteed to receive the physical renewable product directly. Instead, the system ensures that an equivalent amount of CO_2 neutral fuel is supplied to the market as it's currently done for bio mandate based on REDII/REDIII, adhering to sustainability and environmental responsibility principles based on renewable energy directive-approved certification schemes.

While physical tracking offers conceptual clarity, mass balancing achieves the same end goal — verifiable carbon neutrality — while offering a crucial advantage: it removes CNF-specific infrastructure availability as a barrier. By decoupling carbon compliance from the physical fuel path, mass balancing unlocks the entire existing fueling network immediately, allows CNF to scale fast, and ensures drivers can refuel anywhere without disruption.

It's a practical, future-ready approach that delivers environmental integrity while accelerating adoption at the pace the climate challenge demands. The combination with a digital software solution further enhances the robustness of the monitoring technology while taking full advatange of the existing infrastructure.

Customer & Retail Perspectives

Advantages:

- Flexibility
- High Scalability
- Low-cost barrier to entry
- Technology Availability and Fast Implementation
- Ease of implementation, wide network coverage and high customer acceptance
- Enhanced monitoring and flexibility mechanisms
- Mass balance already implemented across all member states and further integrated through the Union Database
- Regulatory geofencing capability

Disadvantages:

- Special attention regarding vulnerability to data latency and transmission failures necessary
- Increasing effort to reduce susceptibility to system failures by multi trust center approach
- Data privacy and GDPR compliance as for all digital systems demands special care
- Limitations in EU's external border fuelling flexibility if implemented without regulatory geofencing
- Limited Digital Infrastructure Availability Initially, which can be quickly implemented.

Regulatory Assessment

Upstream part: Mass balancing (See mass balancing in option 9).
Downstream part: Digital Fuel Tracking System (See DFTS in option 3 and 7).

Summary of the WGMM Evaluation Matrix

#	METHODOLOGY	TRACKING METHOD	DETECTION METHOD	INDUCEMENT SYSTEM	FUEL COMPATIBILITY
1	Mechanical adaption of tank filler / nozzle	Physical	Mechanical	Not required	Gaseous and Liquid fuels
2	Fuel marker along upstream and downstream (sensor in vehicle)	Physical	Sensor	YES	Liquid fuels
3	100% digital tracking from upstream to downstream (DFTS w/ digital handshake)	Physical	Electronic by re-using existing data	YES	Gaseous and Liquid fuels
4	Hybrid approach - upstream: fuel marker & sensor until EU border - downstream: DFTS w/ digital handshake	Physical	Sensor & Electronic	YES	Liquid fuels
5	Vehicle On-board Fuel Detection Function	Physical	Sensor	YES	Liquid fuels
6	Vehicle On-board Fuel Molecular Sensor	Physical	Existing Engine Sensor	YES	Liquid fuels
7	Bidirectional Communication between vehicle and gas station	Physical	Electronic	YES	Gaseous and Liquid fuels
8	EU market exclusively supplied with CNF	Physical	NR	Not required	Gaseous and Liquid fuels
9	Mass-balanced CNF supply to each CNF vehicle	Virtual	None	NO	Gaseous and Liquid fuels
10	Fuels Usage Balancing - FUB	Virtual	Electronic	YES	Gaseous and Liquid fuels
11	Combined mass balancing - DFTS w/ digital handshake	Virtual	Electronic	YES	Gaseous and Liquid fuels

WGMM

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