# Final report

## Project details

| | |
|---|---|
| **Project title** | Biometanol på danske tankstationer<br>Bio methanol on Danish petrol stations |
| **File no.** | J.nr. 64020-1047 |
| **Name of the funding scheme** | EUDP 2020-I |
| **Project managing company / institution** | Danish Technological Institute |
| **CVR number** (central business register) | DK 5697 6116 |
| **Project partners** | HMK Bilcon<br>Circle K<br>Danish Methanol Association<br>FDM – United Danish Motorists<br>Go'on Gruppen<br>City of Copenhagen<br>OK AMBA<br>Scantune<br>City of Skanderborg |
| **Submission date** | 10 February 2026 |

# Summary

## Project summary:

### The purpose of the project

According to the latest projections from the Danish Energy Agency, Denmark will rely on fossil fuels for 92% of its transport sector by 2030 if no further initiatives are taken. Methanol derived from renewable sources is currently one of the most promising alternative fuels, but its potential has not yet been utilized.

A previous study had identified M85, a blend of 85% methanol and 15% regular gasoline, as the most suitable bio-methanol blend for both summer and winter operation in Denmark. It also showed that older gasoline vehicles will run well on M85. The car models tested in this project included recent models with turbo charging and direct gasoline injection. These cars required an installation of additional engine control units ("Flex Fuel Kits") to run on M85. The study also investigated how much methanol could be added to a gasoline blend for use in gasoline vehicles without flex fuel kits.

The project aimed at converting modern gasoline cars to run on M85. This blend is fundamentally suited for gasoline engines due to the octane number, density and vapor pressure being in the same range as regular gasoline. However, since methanol has a lower specific energy content than gasoline, adjustments are necessary to obtain equal performance.

Flex Fuel Kits are generally used to convert older gasoline cars to run on E85, a blend of 85% ethanol and 15% gasoline. Since ethanol shares similar properties with methanol as a fuel, it was considered a good starting point. Currently, there are no specific methanol conversion kits available on the market.

The design and approval of methanol fueling stations for public use were established in various locations. However, due to economic constraints, only one station was completed.

### Results, conclusions and perspective

- The project showed that a significant number of existing vehicles could be converted to run on 85% methanol (M85) using only software modifications, without any mechanical changes. The software primarily increased the volume of fuel injected into the engine to meet standard combustion conditions.

- Some vehicles could only accommodate a lower methanol percentage, such as 56% (M56), due to mechanical limitations of the stock fuel injection system. However, it was also possible to replace the stock injectors with larger ones.
- Emission tests on the converted vehicles in the project were acceptable, allowing them to pass a standard PTI (Periodical Technical Inspection) and be legally driven on the roads.
- The project also demonstrated a supply path for methanol and gasoline blends, with all necessary refueling equipment and local permissions in place.
- Despite technically promising outcomes, the project was ultimately halted due to a lack of demonstration vehicles. The main reasons included uncertainty regarding insurance, warranties, and the resale value of the demonstration cars. Additionally, several practical and organizational factors led to the project's premature conclusion.
- The increasing attractiveness and affordability of electric cars significantly contributed to the conclusion that methanol conversions were not the most economical option for municipal fleets in Denmark at that time.
- While the passenger car market in Denmark was soon expected to be dominated by electric vehicles, the global demand for combustion engines and renewable fuels continued to rise. This had been clearly stated by the International Energy Agency (IEA) and other analysts for years (see e.g., IEA Market Report for Renewable Fuels 2024).
- The approach used in this project can also be applied to smaller boats, garden machinery, and other niches that use gasoline. Much of the knowledge gained can also be transferred to more sophisticated dual-fuel systems, such as those used on larger ships or construction machinery.

## Projektresumé

### Formålet med projektet

Ifølge de seneste fremskrivninger fra Energistyrelsen vil Danmark være afhængig af fossile brændstoffer til 92% af transportsektoren i 2030, hvis der ikke iværksættes yderligere initiativer. Methanol, som stammer fra vedvarende kilder, er i øjeblikket et af de mest lovende alternative brændstoffer, men dets potentiale er endnu ikke blevet fuldt udnyttet.

En tidligere undersøgelse har identificeret M85, en blanding af 85% methanol og 15% konventionel benzin, som den mest egnede bio-methanol-blanding til både sommer- og vinterbrug i Danmark. Undersøgelsen viste også, at ældre benzinbiler fungerer godt med M85. De bilmodeller, der blev testet i projektet, omfattede nyere modeller med turboladning og

direkte benzinindsprøjtning. Disse biler krævede installation af ekstra motorkontrolenheder, ("Flex Fuel Kits") for at kunne køre på M85. Undersøgelsen belyste også, hvor meget methanol der kan tilsættes en benzinblanding til brug i benzinbiler uden flex fuel kits.

Målet med projektet var at ombygge moderne benzinbiler til at køre på M85. Blandingen er grundlæggende velegnet til benzinmotorer, da oktantallet, densiteten og damptrykket ligger tæt på værdierne for konventionel benzin. Da methanol dog har et lavere energiindhold end benzin, er der behov for justeringer for at opnå samme ydeevne.

Flex Fuel Kits bruges generelt til at ombygge ældre benzinbiler til at køre på E85, en blanding af 85% ethanol og 15% benzin. Da ethanol har lignende egenskaber som methanol, blev det betragtet som et godt udgangspunkt. Der findes dog i øjeblikket ingen specifikke konverteringssæt til methanol på markedet.

Design og godkendelse af methanoltankstationer til offentlig brug blev etableret flere steder, men på grund af økonomiske begrænsninger blev kun én station færdiggjort.

**Resultater, konklusioner og perspektiv**

- Projektet viste, at et betydeligt antal eksisterende køretøjer kunne ombygges til at køre på 85% methanol (M85) udelukkende ved hjælp af softwareændringer, uden behov for mekaniske ændringer. Softwaren øgede primært mængden af brændstof, der blev indsprøjtet i motoren, for at opretholde standard forbrændingsbetingelser.

- Nogle køretøjer kunne dog kun håndtere en lavere methanolprocent, såsom 56% (M56), på grund af mekaniske begrænsninger i det originale brændstofindsprøjtningssystem. Det var dog også muligt at erstatte de oprindelige injektorer med større.

- Emissionstestene for de ombyggede køretøjer i projektet var tilfredsstillende, hvilket gjorde det muligt for dem at bestå en standard periodisk teknisk inspektion (PTI) og lovligt køre på vejene.

- Projektet demonstrerede også en forsyningskæde for methanol- og benzinblandinger med alt nødvendigt tankudstyr og lokale tilladelser på plads.

- På trods af teknisk lovende resultater blev projektet til sidst stoppet på grund af mangel på demonstrationskøretøjer. De primære årsager var usikkerhed omkring forsikring, garantier og gensalgsværdi af demonstrationsbilerne. Derudover bidrog flere praktiske og organisatoriske faktorer til projektets for tidlige afslutning.

- Den stigende tiltrækningskraft og øgede prisvenlighed for elbiler bidrog til konklusionen om, at methanolkonverteringer ikke var den mest økonomiske løsning for kommunale bilflåder i Danmark på det tidspunkt.

- Selvom det forventedes, at markedet for personbiler i Danmark snart ville blive domineret af elbiler, fortsatte den globale efterspørgsel efter forbrændingsmotorer og vedvarende brændstoffer med at stige. Dette var blevet klart understreget af International Energy Agency (IEA) og andre analytikere i årevis (se f.eks. IEA Market Report for Renewable Fuels 2024).

- Fremgangsmåden, der blev anvendt i dette projekt, kan også anvendes på mindre både, havemaskiner og andre nicher, der bruger benzin. Meget af den opnåede viden kan også overføres til mere avancerede dual-fuel-systemer, såsom dem, der anvendes på større skibe eller entreprenørmaskiner.

# Project objectives

The objective of this project was to experimentally develop a framework for commercial-scale supply of bio-methanol for spark-ignited (i.e., gasoline) vehicles.

The specific objectives of this project were:

- to develop high methanol fuel blends, including additives, that can be used year-round under climatic conditions found in Denmark
- to develop, implement and evaluate an infrastructure to blend and distribute methanol-based engine fuels
- to develop a procedure for converting existing vehicles from gasoline to high methanol blend operation, including installation of sensors that allow to run on arbitrary methanol-gasoline blends
- to assess and compare the performance of converted vehicles running high methanol blends under real operation over a prolonged time and in different seasons.

For the vehicles, the aim was to find a demonstration host that would accept a level of inconvenience in their daily use of the vehicles for the sake of innovation.

Thus, the technology developed and demonstrated in the project was:

1. Traditional gasoline cars running road-legally on M85 only using software upgrades.
2. Dispensers for refueling in the public domain.

# Project implementation

The investigation of Flex-Fuel Kits began with an earlier project, EUDP J.nr. 64018-0719, which also was part of IEA-AMF Annex 56. Several oil companies in Denmark had shown an interest in the concept, and the motorists association FDM was also seeking technologies to complement electrification. Based on this interest, a new consortium was formed. The partnership was selected to cover all relevant aspects of a major Danish rollout of bio methanol for vehicles. The participants in the project were Danish Methanol Association, HMK Bilcon, Danish Technological Institute, Circle-K, OK a.m.b.a, Scantune, FDM, City of Skanderborg, City of Copenhagen and Go'on.

The Danish Technological Institute led the project management, provided technical problem-solving, and conducted accredited emission measurements. The Danish Methanol Association was responsible for manufacturing, shipping, handling, and ensuring sustainability. Circle-K, OK AMBA, and Go'on were involved in the preparation, installation, and operation of refueling stations with M85. HMK Bilcon handled UN classifications, transport safety, and tank coating. Scantune served as the importer and distributor of Flex Fuel Kits, optimizing them for M85, and addressing measurement and problem-solving tasks. FDM managed car operations, conducted car engineering studies, and offered consumer advice. The City of Copenhagen and the City of Skanderborg were responsible for the operation and transport of vehicles, as well as user involvement.

Overall, the project faced several challenges that needed to be addressed from the outset. Obtaining permits was the main concern from the beginning. Acceptance from users was another issue. Based on experience, we knew that vehicle operators would not respond well to poor performance or inconvenience. Insurance, depreciation and the disruption of existing purchase agreements were also major concerns.

There were significant delays in the planning and approval of refueling sites. Many plans had to be changed or abandoned due to roadworks or other external factors. Ultimately, the cost of establishing fueling stations in the public domain proved to be too high. Only one installation was completed at the privately owned facility JyllandsRingen

On the user side, there was initially a high degree of interest, because M85 offered a shortcut to climate-friendly mobility. However, interest clearly declined as electric vehicles gained popularity and many cities decided that electrification was the only path forward. In the end, it was not possible to establish a suitable demonstration fleet due to lack of demand.

It was assumed from the start that the partnering municipalities had full control over their vehicle fleets and could freely manage them. Discovering that municipalities generally do not own vehicles but predominantly lease them instead meant that the partnering cities in the

project were unable to fulfill their intended contributions. It was not possible to secure a general guarantee on the resale value of modified cars. Thus, the financial risk became too large.

# Project results

The project was terminated by mutual agreement because the market potential was smaller than expected, making it impossible to establish an attractive business case for car owners. During the project, the demand for electric vehicles surpassed the appeal of the M85 solution.

Before the decision to terminate was made, the partners made significant efforts to find alternative fleets of vehicles. Many options were explored, but none could meet the needs of the end users.

The issues of insurance and vehicle depreciation presented another major challenge. Despite numerous offers and negotiations, no financially viable solution could be achieved.

However, meaningful technological results was generated in the project, which will be presented in the following section.

**Obtained technological results**

A total of 11 vehicles were converted into M85 cars. The vehicles were selected based on number of criteria that included suitability for conversion, availability, and geographical considerations regarding fuel supply. The selected vehicles underwent a technical review, and baseline emissions were verified at Danish Technological Institute before being delivered for conversion. The conversion process initially involved power measurement and partial load measurements on a dynamometer. A strategy for the conversion was then established, which could involve:

1. **Modifications to the calibration settings of the Engine Control Unit (ECU):** The ECU is read, and the software is reverse engineered to adjust fuel supply tables through repeated dynamometer tests, a process that is time-consuming and demands deep expertise in engine management systems.
2. **Installation of a programmable module on the peripheral system of the fuel injection (piggyback):** A piggyback device is installed between the engine's ECU and the fuel injectors to intercept and convert signals to desired values, with programming being similarly time-consuming.
3. **A combination of both methods**: If satisfactory performance could not be achieved with one method alone, a combination of both methods was attempted, although this increased costs to an unacceptable level.

The primary technical challenge was the cold-start capabilities. The difference in the amount of fuel that needed to be injected was significant, sometimes requiring 80-90% more fuel compared to standard gasoline operation. This proved problematic, particularly during cold starts, as the fuel would condense on the cold surfaces of the engine, even if it were possible to deliver the greatly increased amount to the engine. These conditions resulted in difficult cold starts, problematic emission levels, and irregular operation during the first few minutes after startup. This issue could not be resolved within the available budget. Additionally, methanol's flammability at low temperatures was an ongoing concern. Throughout the project, various methanol/gasoline mixtures were tested to determine a satisfactory limit for winter operation. Most vehicles exhibited a slight increase in power, which was problematic concerning the Danish Road Safety Agency's condition number 5. Reducing the power would have significantly increased costs.

The percentage of methanol acceptable for each vehicle after conversion is shown in Figure 1. The differences arise from the varying dimensioning of fuel nozzles, with some vehicles having more overcapacity and a wider adjustment range than others. The 12th vehicle shown in the figure, Geely Emgrand 6, was factory-produced to run on either pure methanol or gasoline, and thus it had no such limitations.

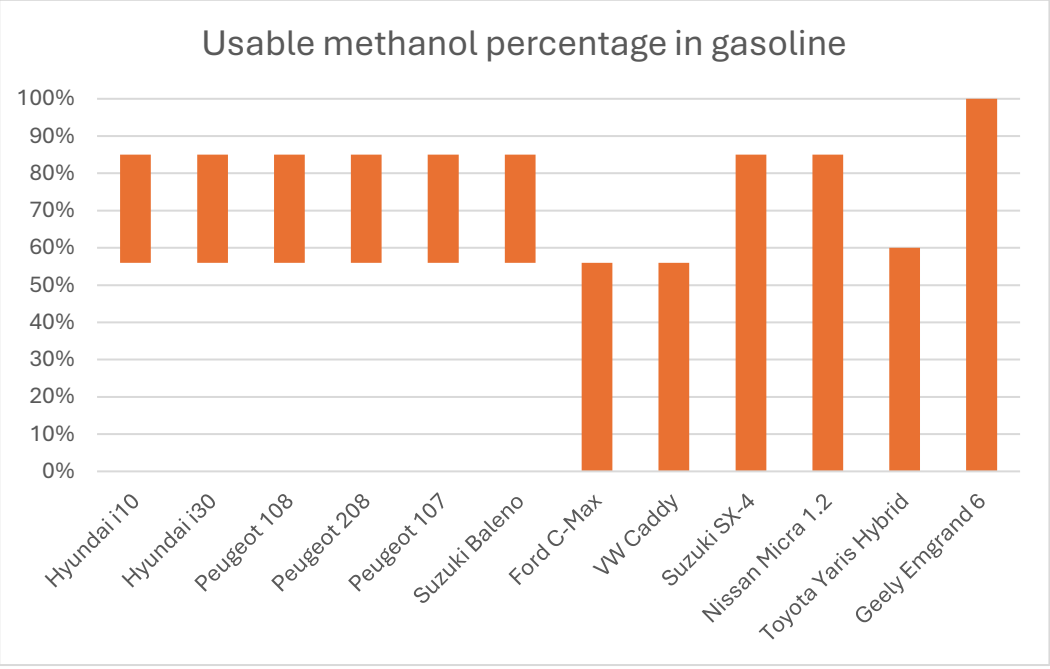


Figure 1 Highest and lowest methanol content confirmed after conversion of the vehicles.

For the most part, emissions were within legal limits for new vehicles. Exceptions included two cases of high CO and two cases of high NOx. High CO comes from poor adjustment of the cold-start program, while high NOx was due to an excessively high overall excess-air ratio. Both issues could presumably have been rectified with more time.

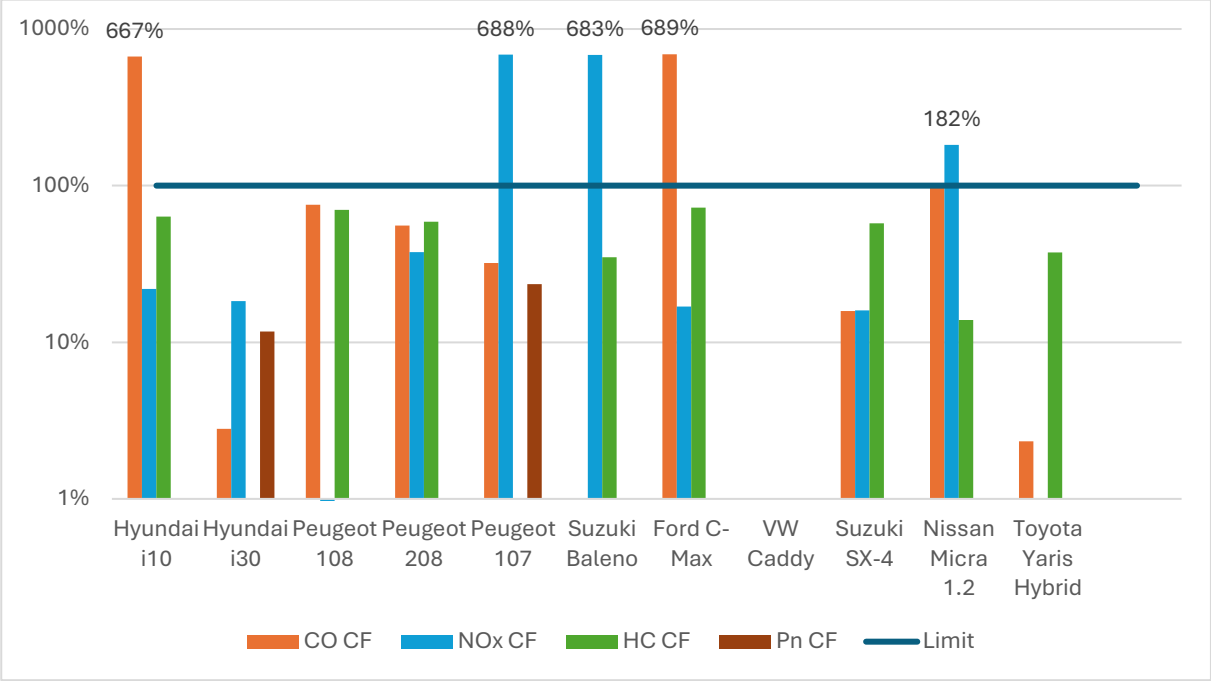


Figure 2 Conformity of emissions on converted vehicles.

Since there was no technical service able to perform a legally valid emission test in Denmark, the consortium requested permission to conduct the tests in an accredited laboratory at DTI instead. This solution was accepted by the Danish Road Safety Agency (Færdselsstyrelsen) under the following conditions:

1) The vehicles may be used only for a limited period from February 2021 to September 2023.
2) The vehicles shall be returned to their original state and pass a periodical technical inspection at the end of the period.
3) Operation of the vehicles shall be supervised by DTI and FDM and operation shall be suspended in the event of irregularities affecting proper usage on public roads.
4) A test report shall contain an assessment of the risk of accelerated ageing, leakages etc., which shall be routinely monitored.
5) The engine power of the vehicles must not be increased.
6) The vehicles shall be appropriately labelled, and the users shall be properly informed.

To ensure legal operation in Denmark, it was also necessary to consult with tax authorities, as vehicle taxes depend on fuel consumption and fuel type. Since methanol blends are not in the current list of acceptable fuels, it was decided that vehicles for M85 could pass inspection with gasoline as the registered fuel.

In terms of fuel quality, an additive package was chosen and tested by OK AMBA and their suppliers. Many options were evaluated based on greenhouse gas reduction, engine wear,

toxicity, distribution etc. This work resulted in a market-ready fuel blend, which differs from chemically pure methanol. Just as raw gasoline is not directly suited for automobiles, most fuels need some form of chemical enhancement before being ready for the mass market. This includes emulsifiers, lubricants, detergents, co-solvents etc.


Figure 3 Fuel dispenser from OK AMBA.

Figure 4 Blender pump solution from Dover Group.

The primary target group for this solution is vehicle owners who are not prepared to switch to electric cars, either due to financial reasons or a lack of charging infrastructure. When produced from manure, M85 would leave a carbon footprint comparable to that of electric vehicles but at a lower investment cost.

The project results have been disseminated through various relevant channels. Project partners have communicated the results and insight in Danish Television, radio, webpages, on Danish Methanol Association channels, and Erhvervsklubben.

# Utilisation of project results

It is likely that the fuel dispensers and storage facilities will be utilized in Denmark's many seaports, where ferries and fishing vessels are seeking for alternatives to complement electrification. The engine technology will possibly be transferred to non-road machinery, rally racing, go-karts, smaller boats, and other applications.

As electric vehicles outperform the technical solution in the Danish market, the commercial outcome is not as expected. Leasing companies, dealerships, insurance companies, fleet owners, consumers, and most oil and energy companies are extremely reluctant to pursue any alternative direction than electrification. This is a valuable lesson.

Besides the competitive market, there are several other sales barriers for M85 for vehicles. Auto manufacturers do not support M85, and neither do leasing companies, dealerships, nor insurance companies. The cost of establishing M85 fuel stations is much higher than initially anticipated. Consumers are not ready to accept any downsides in terms of mobility, range or reliability. As a minimum, cars must also be able to run on conventional fuel when needed. It is not expected that the sum of these barriers can be overcome in the foreseeable future.

However, new market opportunities have emerged, such as marine methanol. In the marine sector, there has been significant investment in methanol-ready container ships, reflecting the growing interest in methanol as a viable alternative in maritime applications. Thus, maritime shipping, which plays a significant role in Denmark's economy, will require substantial amounts of methanol in the future to meet their goals.

Meanwhile, the market for alternative transport fuels in Europe is dominated by Biodiesel/HVO, natural gas/CNG/Biogas, autogas/propane, E85, and hydrogen. However, in Denmark, only hydrogen is being seriously considered for the future. The primary competing solution remains battery electric cars, which have experienced a surge in popularity.

However, while passenger cars in Denmark may not be the ideal starting point for implementation of methanol, as other sectors have a greater need, passenger cars will require alternatives to electrification on a global scale. Generally, there remains a continued need for alternative fuel solutions in sectors that are difficult to electrify.

# Project conclusion and perspective

Technically, modern gasoline engines can run on methanol, but the fuel systems need to be modified either electronically or physically. Permission to use such modified vehicles on the road, along with a PTI-report, was obtained in the project. Modifying older cars is relatively straightforward, but with newer vehicles, the electronic engine management systems are protected against turning and hacking, making modifications much more difficult. No vehicle manufacturer currently allows or condones such modifications. Type-approved methanol vehicles are only available in China.

Methanol blends can be distributed in the same way as gasoline. This distribution can occur centrally via refineries and traditional fuel depots or through a separate stream from methanol producers or stockists directly to consumers. The project successfully obtained all necessary plans and permissions to install methanol fueling stations

Despite these efforts, the project team was unable to develop an attractive market offer for M85 that could compete with electric cars. As a result, there does not appear to be a future for M85 in the Danish passenger car market. However, the maritime sector is rapidly moving towards methanol combustion engines, suggesting that the technology will endure. This shift opens opportunities for other types of conversions that could become relevant for heavy machinery, generators, outboard engines, and more.

While Denmark's passenger car market is poised to be dominated by electric vehicles, the global demand for combustion engines and renewable fuels continues to rise. This has been clearly stated by the International Energy Agency (IEA) and other analysts for years. The approach used in this project could also be applied to smaller boats, garden machinery, and other niches currently using gasoline. Additionally, much of the knowledge gained can be adapted to more sophisticated dual-fuel systems, such as those used on larger ships or construction machinery.

# Appendices

- DTI website on M85: https://www.teknologisk.dk/ydelser/bilejere-skal-teste-co2-venlig-bio-metanol/42363
- IEA-AMF report on Methanol as motor fuel : https://iea-amf.com/content/projects/map_projects/56
- IEA Market Report Renewable Fuels: https://www.iea.org/reports/renewables-2024/renewable-fuels