Report

Well to tank assessment – diesel fuel MK1 and EN 590

2012-08-13
Report no 127057, rev. 2

Ecotraffic

Content

Appendices

1. Certificate of Quality, SD-DIESEL EUR VI B7, PREEM AB, FAT.111108.SDEUROVIB7
2. Certificate of Quality, SD-DIESEL EUR VI B7, PREEM AB, FAT.111114.B7
3. Summary of other steps than production in the WTT chain

Bibliography

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Författare	Peter Ahlvik och Lars Eriksson		

1. Sammanfattning (Swedish summary)

De svenska miljöklassade dieselbränslena introducerades i början av 1990-talet efter omfattande tester och undersökningar av inverkan på hälsa och miljö från olika dieselbränslespecifikationer. Det mest ”miljövänliga” av dessa drivmedel var miljöklass 1, benämnd MK1. Specifikationen för MK1 innehöll många parametrar för att minska hälsoeffekter från avgaserna, t.ex. ett lågt innehåll av polycykliska aromatiska kolväten, totala aromater och svavel.

När MK1 drivmedlet introducerades på marknaden var dieselfordon generellt inte utrustade med någon form av katalytisk avgasefterbehandling. Oxidationskatalysatorer introducerades kort därefter på lätta fordon men endast relativt få tunga fordon hade katalysatorer. Senare introducerades dieselpartikelfilter (DPF) som eftermonteringslösning på tunga fordon, mestadels bussar. Efter lanserinen av den första framgångsrika DPF:en för personbilar av Peugeot år 2000 fick även denna teknik ett snabbt genomslag.

Eftersom modern avgasefterbehandlingsutrustning har minskat avgasemissionerna har behovet av ett ”renare” dieselbränsle ifrågasatts. Det har också diskuterats att energieffektiviteten i drivmedelsproduktionen kan vara lägre för MK1 dieselbränslet än för EN 590 bränslet och att utsläppen av klimatgaser kan vara högre. Syftet med studien som rapporteras här var att undersöka dessa frågor.

För att ytterligare studera inverkan av drivmedelsproduktion på effektivitet och utsläpp av klimatgaser gav Trafikverket Ecotraffic i uppdrag att genomföra denna studie, som är en del av ett mycket större regeringsuppdrag. Det arbete som rapporteras här har utförts i nära samarbete med oljebolag och raffinaderier.

Basåret för analysen överenskoms till 2010, bortsett från ett raffinaderi som var stängt för uppgradering under 2010, så i detta fall valdes 2009 i stället. På grund av sekretess kan det mesta av bakgrundsdata och enskilda resultat från varje raffinaderi inte publiceras i denna rapport.

Två huvudsakliga scenarier beaktades:

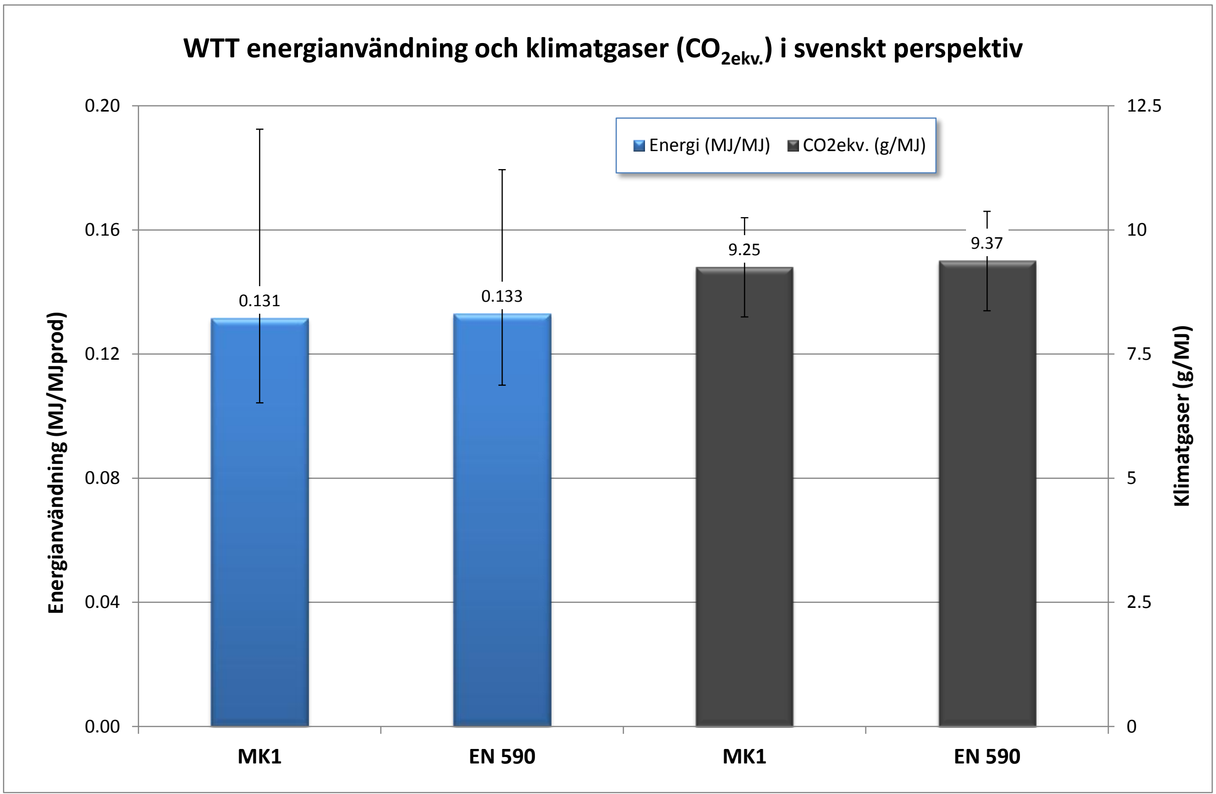
- Produktion av MK1 dieselbränsle för den svenska marknaden
- Produktion av EN 590 dieselbränsle för den svenska marknaden som substitut för nuvarande produktion av MK1 drivmedel

Eftersom produktionen av EN 590 drivmedel för andra marknader än Sverige kan påverkas ifall MK1 eller EN 590 produceras för den svenska marknaden undersöktes energieffektiviteten och utsläpp av klimatgaser både i svenskt och globalt perspektiv.

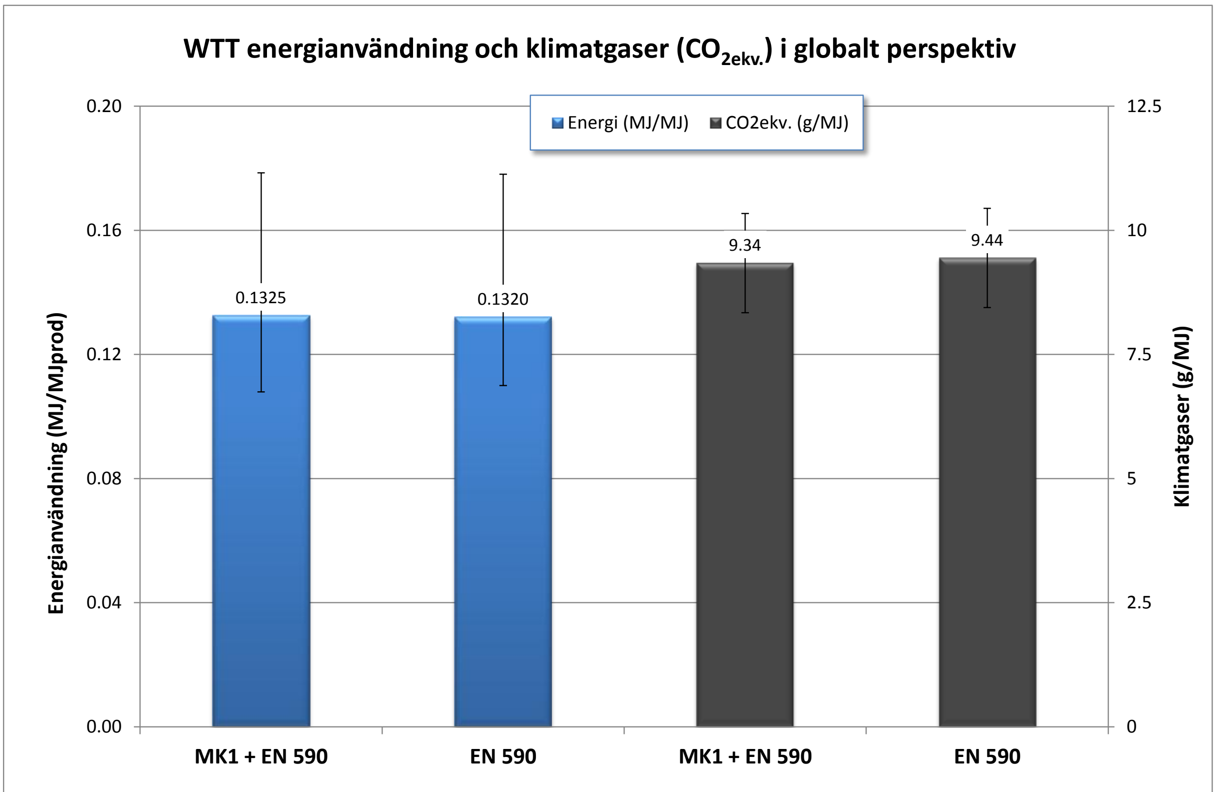
I Figuren S1 visas resultaten för de viktade medeltalen för energianvändning och klimatgaser (i CO_2 ekvivalenter) i det svenska perspektivet. För både energianvändning och CO_2 visas det lägsta och det högsta värdet i varje fall som ”felstaplar”.

Resultaten i Figur S1 visar en fördel för MK1 drivmedlet både vad gäller energianvändning och klimatgaser. Emellertid bör man också notera att skillnaderna mellan enskilda raffinaderier är stor, dvs. mycket större än skillnaden mellan de viktade medelvärdena. Den huvudsakliga orsaken till detta resultat är att några raffinaderier använder en ström av ”straight run” (direkt destillerat) dieselbränsle för produktion av MK1 bränsle. För EN 590 används krackning och det resulterar i mer processande för att producera detta drivmedel jämfört med MK1. Mer processande ökar också energianvändningen och utsläppen av klimatgaser.

I Figur S2 visas resultaten för energianvändning och utsläpp av klimatgaser (i CO_2 ekvivalenter) i det globala perspektivet. Benämningen ”MK1 + En 590” avser att MK1 bränsle produceras för den svenska marknaden och EN 590 produceras för alla andra marknader.



Figur S1. WTT resultat för energianvändning och klimatgaser i ett svenskt perspektiv



Figur ES2. WTT resultat för energianvändning och klimatgaser i ett globalt perspektiv

Resultaten i Figur S2 visar en försumbar skillnad mellan både energianvändning och klimatgaser för båda scenarierna i det globala perspektivet. Den största orsaken till den försumbara skillnaden i detta fall är att den ström av ”straight run” som i några raffinaderier används för att producera MK1 bränsle nu blandas in i hela bränslepoolen för EN 590. Därigenom ”förbättras” EN 590 med avseende på energianvändning och utsläpp av klimatgaser jämfört med fallet när MK1 bränsle också produceras.

Följande generella slutsatser från denna studie kan dras:

- Arbetet med och tidsramarna för att samla in basdata för studien från raffinaderierna underskattades avsevärt.
- För att bedöma data och beräkningar i raffinaderier krävs ingående kunskaper om raffinaderiprocesser som experter i LCA och WTW områden som regel inte har. Denna expertis fanns tillgänglig på Chalmers Tekniska Högskola.
- Det finns skillnader vad gäller systemgränser och metodik mellan raffinaderierna som vi fullt ut inte kunnat beakta.
- Skillnaderna i specifikation mellan MK1 och EN 590 bränslena har minskat något under åren, vilket mest troligt också har minskat skillnaden i produktion jämfört med förhållandena tidigare.
- Under arbetets gång blev det uppenbart att, utöver de två scenarierna som satts upp före studien (produktion av MK1 och EN 590 för den svenska marknaden), var det också nödvändigt att utvärdera energianvändning och klimatgaser både i ett svenskt också i ett globalt perspektiv.
- Viktning av resultaten från varje raffinaderi har gjorts enligt producerade volymer på energibas.
- I det svenska perspektivet har MK1 dieselbränsle en liten fördel för både energianvändning och klimatgaser.
- I det globala perspektivet är det praktiskt taget inga skillnader i energianvändning och klimatgaser mellan de båda bränslekvaliteterna.
- Av sekretesskäl kan ingen ingående diskussion om enskilda raffinaderier göras i föreliggande rapport.
- Skillnaderna i resultat mellan raffinaderierna är avsevärda och skillnaden i relativa tal är störst för energianvändningen. Gapet mellan de raffinaderier som ligger högst respektive lägst är mycket större än den viktade medelskillnaden mellan de två drivmedlen.
- En av de största skillnaderna mellan data från raffinaderierna verkar vara hur väte behandlas i beräkningarna. Ett försök att ta hänsyn till detta gjordes genom att utvidga systemgränserna till att även inkludera bensin. Dessutom behandlades all vätgas som en ”pool”. Nya data levererades av några av raffinaderierna och nya beräkningar gjordes av oss för andra. Emellertid ändrades inte de viktade resultaten speciellt mycket genom ökningar i några raffinaderier och minskningar i andra. Mer arbete bör göras inom detta område.
- Före detta arbete hade vi generellt förväntat oss en något högre energianvändning och emissioner av klimatgaser för MK1 produktion jämfört med EN 590 produktion, helt enkelt genom ökat processande i MK1 fallet. Emellertid blev det uppenbart i genomgången av basdata att vilket raffinaderi som helst, oavsett ifall MK1 eller EN 590 är huvudprodukt, har optimerat sin produktion för det aktuella bränslet. Således, även om vi har signifikanta skillnader mellan MK1 och EN 590 produktion – dvs. högre i vissa

fall och lägre i andra fall – tenderar dessa skillnader att jämna ut sig när vi viktar ihop resultaten.

- Jämfört med medelvärdet för europeiska raffinaderier, JEC studien och Solomon data har de fem raffinaderierna i de nordiska länderna högre energieffektivitet och lägre emissioner av klimatgaser.
- Studien tillhandahåller data från WTT steget som, tillsammans med data för TTW från andra studier, möjliggör en beräkning av full WTW energianvändning och emissioner för de två dieselkvaliteter som studerats.

En slutlig kommentar i denna rapport kan vara att eftersom skillnaderna i energianvändning och emissioner av klimatgaser mellan de båda bränslekvaliteterna är relativt små; kanske andra parametrar kan utgöra underlag för ett beslut om vilken av de två bränslekvaliteterna som bör stödjas.

2. Executive summary

The Swedish environmentally classified diesel fuels were introduced in the early 1990´s after extensive tests and investigations of the impact on health and environment from various diesel fuel specifications. The most “environmentally friendly” of these fuels was the environmental class 1, denoted MK1 (after the Swedish synonym for environmental class, miljöklass). The specification of the MK1 fuel had many parameters for improved health effects of the exhaust, e.g. low content of polycyclic aromatic hydrocarbons, total aromatics and sulphur.

When the MK1 fuel was introduced on the market, diesel vehicles in general were not equipped with any catalytic aftertreatment. Oxidation catalysts were introduced shortly after on light-duty vehicles but only relatively few heavy-duty vehicles had catalysts. Later, diesel particulate filters (DPFs) were introduced as retrofit solutions on heavy-duty vehicles; mostly buses. After the first successful DPF on a passenger car was launched by Peugeot in 2000, also this technology received a rapid breakthrough.

Since modern exhaust aftertreatment equipment has reduced exhaust emissions, the need for a “cleaner” diesel fuel has been challenged. It has also been discussed that the energy efficiency in fuel production might be lower for MK1 diesel fuel than for EN 590 fuel and that the emissions of climate gases might be higher. The scope of the work reported here was to investigate these issues.

In order to further study the impact of fuel production on efficiency and emissions of climate gases, Trafikverket commissioned Ecotraffic to conduct this study, which is part of a much larger commission from the Swedish Government. The work reported here has been carried out in close co-operation with oil companies and refineries.

The base year for assessment was decided to 2010, except for one refinery that had an overhaul with shutdown during 2010, so in this case, 2009 was chosen instead. Due to reasons of confidentiality, most of the background data and individual results from each refinery cannot be published in this report.

Two basic scenarios were considered:

- Production of MK1 diesel fuel for the Swedish market
- Production of EN 590 diesel fuel for the Swedish market as substitute for the current MK1 fuel

Since the production of EN 590 for other markets than Sweden might be affected if MK1 or EN 590 is produced for the Swedish market, energy efficiency and emissions of climate gases were investigated both on Swedish and global perspective.

In Figure ES1, the results for the weighted averages of energy use and climate gases (in CO_2 equivalents) on the Swedish perspective are shown. For both energy use and CO_2, the lowest and highest results in each case are shown as “error” bars.

The results in Figure ES1 show an advantage for MK1 fuel both for energy use and climate gases. However, one should also note that the difference between individual refineries is large, i.e. much larger than the differences between weighted averages. The main reason for this result is that some refineries use a stream of straight run diesel fuel for MK1 fuel production. For EN 590, cracking is used and this result in more processing to produce this fuel compared to MK1. Additional processing increases energy use and emissions of climate gases.

In Figure ES2, the results for energy use and emissions of climate gases (in CO_2 equivalents) on the global perspective are shown. The denotation “MK1 + EN 590” refers to that MK1 fuel is produced for the Swedish market and EN 590 is produced for all other markets.

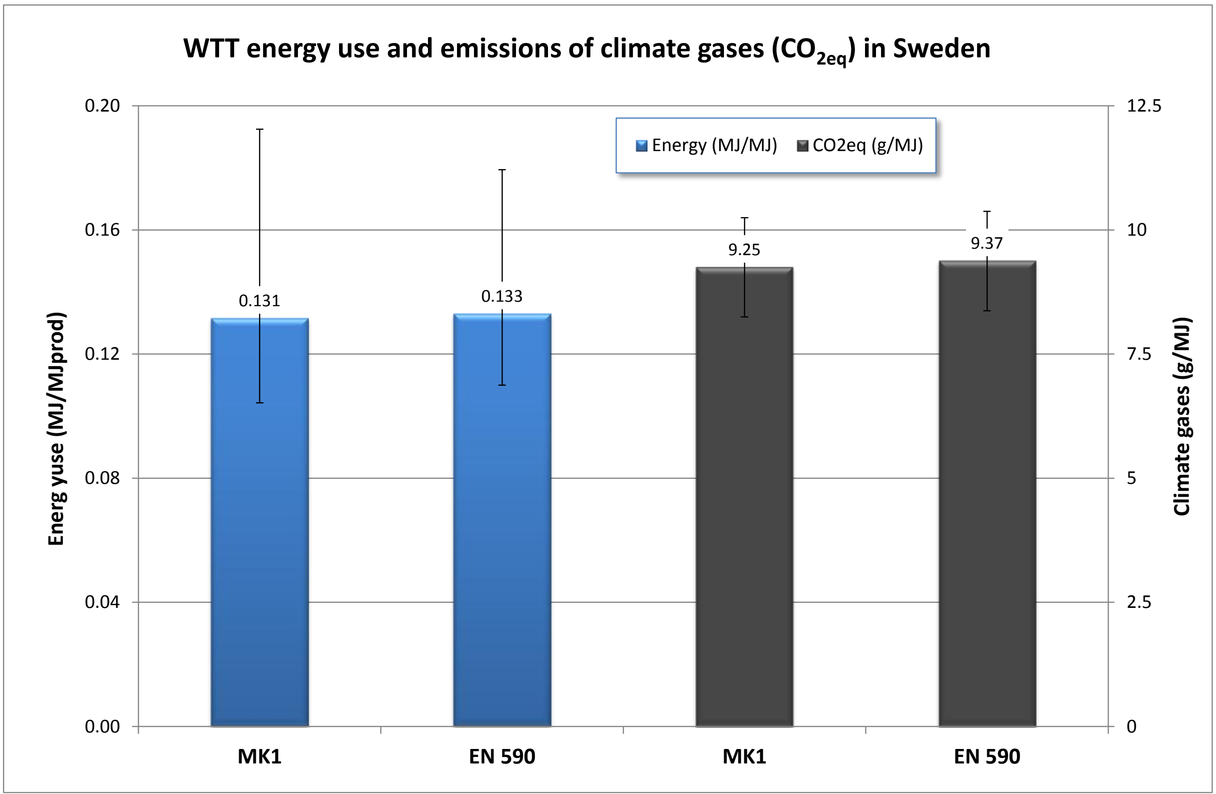


Figure ES1. WTT results for energy use and climate gases in a Swedish perspective

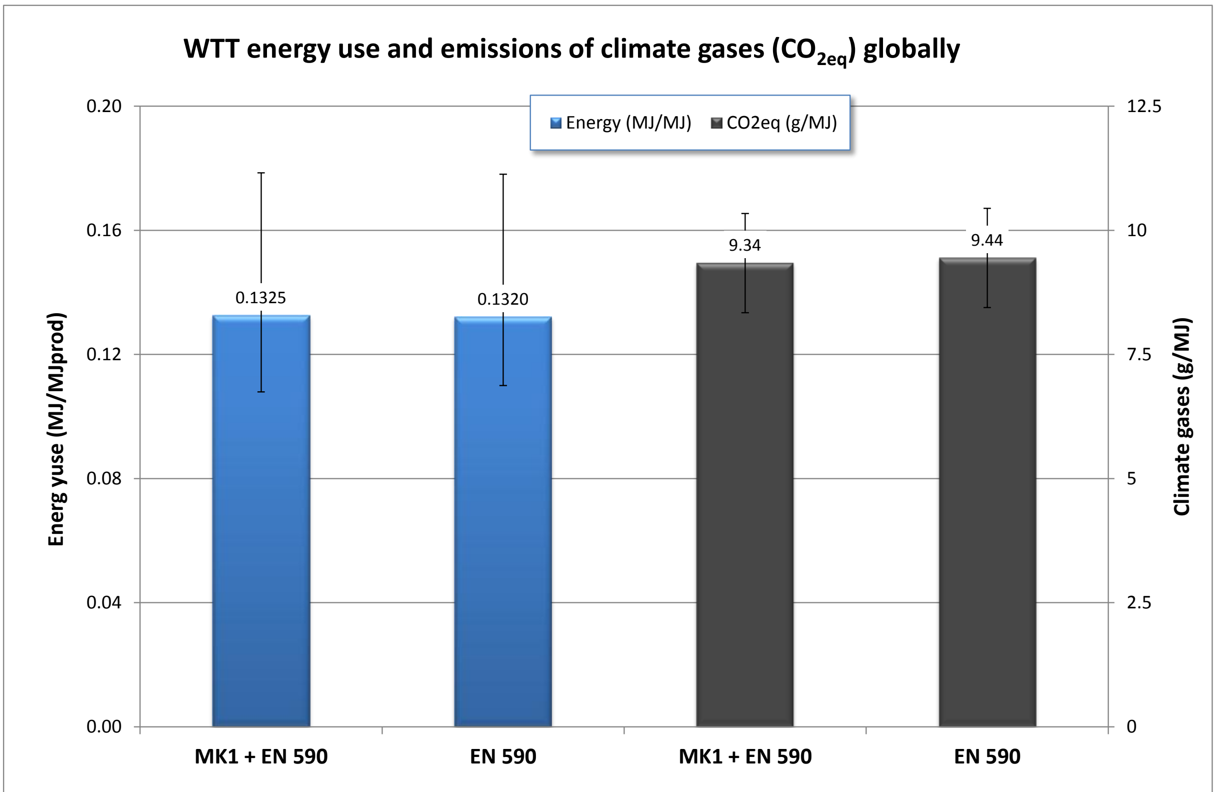


Figure ES2. WTT results for energy use and climate gases in a global perspective

The results in Figure ES2 show a negligible difference between both energy use and climate gases for both scenarios on the global perspective. The main reason for the negligible difference in this case is that the straight run stream that in some refineries is used for producing MK1 fuel is now blended in the whole EN 590 fuel pool. Thus, the EN 590 fuel is “improved” regarding energy use and the emission of climate gases compared to EN 590 production when MK1 fuel is also produced.

The following general conclusions from this study can be drawn:

- The work and timeframe for collecting basic data for the study by the refineries was substantially underestimated.
- In order to assess data and calculations in refineries, in-depth knowledge about refinery processes normally not possessed by experts in LCA and WTW fields is needed. This expertise was available at the Chalmers University of Technology.
- There are differences for the system boundaries and methodology between the refineries that we have not been able to fully take into account.
- The differences in specification between MK1 and EN 590 fuels have been somewhat reduced over the years, which has most likely also narrowed the gap in production between the two fuels compared to the situation in the past.
- During the work it was apparent that, besides the two scenarios set up before the study (production of MK1 or EN 590 for the Swedish market), it was also necessary to evaluate energy use and climate gases both in a Swedish and global perspective.
- Weighting of the results from each refinery has been made according to the production volume on energy base.
- In the Swedish perspective, MK1 diesel fuel has a small advantage for both energy use and climate gases.
- In the global perspective, there is practically no difference in energy use and climate gases between the two fuel qualities.
- Due to reasons of confidentiality, no in-depth discussion about single refineries can be carried out in the present report.
- The differences in results between the refineries are substantial and the difference in relative terms is greatest for energy use. The gap between the highest and lowest refineries is much greater than the weighted average difference between the two fuels.
- One of the greatest differences between data from the refineries seems to be how hydrogen is treated in the calculations. An attempt to take this into account by expanding the system boundaries to include also petrol was made. In addition, all hydrogen produced was treated as a pool. New data were submitted by some refineries and new calculations were made by us for others. However, the total weighted results did not change very much due to that increases for some refineries and decreases for others. More work should be carried out in this area.
- Prior to this work, we had generally anticipated somewhat higher energy use and emissions of climate gases for MK1 production in comparison to EN 590 production, simply due to the additional processing of the fuel in the MK1 case. However, it became apparent by scrutinizing the basic data that any refinery, regardless if MK1 or EN 590 is the main product, has optimized their production for that particular fuel. Thus, although we have significant differences between MK1 and EN 590 production – i.e. higher in some cases and lower in some cases – these differences tend to cancel out when we weigh the results together.

- Compared to average European refineries, the JEC study and Solomon data, the five refineries in the Nordic countries have higher efficiency and lower emissions of climate gases.
- This study provides data from the WTT step that, with TTW data from other studies, enables the calculation of full WTW energy use and emissions for the two diesel fuel qualities studied.

A final remark in this report might be that since the differences in energy use and emissions of climate gases between the two fuel qualities are relatively small, perhaps other parameters should be the basis for a decision about which one of the two fuel qualities to promote.

3. Introduction

Background

The Swedish environmentally classified diesel fuels were introduced in the early 1990´s after extensive tests and investigations of the impact on health and environment from various diesel fuel specifications. Summaries of these test results and corresponding assessments of potential health have been made elsewhere and it was beyond the scope of this study to make yet another summary of this kind or to cite these publications.

Initially, two classes of "cleaner" diesel fuels were introduced on the market in the 1990´s, the so-called environmental class 1 and class 2 diesel fuels. The "ordinary" diesel fuel at that time was denoted environmental class 3. English denotations for the fuels are EC 1, EC 2 and EC 3 (Environmental Class 1, 2 and 3, respectively). However, since the Swedish denotations MK1 – MK3 (miljöklass 1 - 3, respectively) are more common in the literature, MK1 is used here but the EU denotation EN 590 is used in favour of MK3. Two typical fuel analysis of each fuel is provided in the appendices. These are the two test fuels for vehicle/engine testing in parallel projects to this one. The Swedish standard for MK1 fuel is SS 15 54 35:2011 [1] [1] and the corresponding EN 590 standard is EN 590:2009+A1:2010 [2].

The MK1 and MK2 fuels were introduced via substantial tax incentives. Due to technical reasons in the fuel production, MK2 was introduced first in larger quantities but relatively soon, MK1 took over the sales. Already before end of the 1990´s, the market share for MK1 was approaching 100 %. After the increasing interest in biofuels both in pure form and as blending components, it was apparent that the original MK1 and MK2 specifications for tax incentives could not handle issues related to the classifications of blended fuels. Therefore, the Swedish Road Administration (SRA, a predecessor to Trafikverket) was commissioned by the Swedish Government to propose a new environmental classification system for diesel fuels. The results from this work were reported in May 2005 [3]. The main author of the present report participated in this work and submitted a basis report to SRA. Part of this work was to scrutinize old tests and fuel specifications once again. One outcome of this work was a slight change in some fuel parameters, such as e.g. end boiling point. This could somewhat improve the refiner's options to produce this fuel. Furthermore, low-level blending of FAME in MK1 was also enabled with the new specification, simply by setting specifications for each component of the blended fuel. The most recent amendment of the MK1 fuel is the increase in maximum limit for blending with biodiesel [1], which corresponds to similar increase for EN590.

Since the introduction of the environmentally classified fuels in the 1990´s, the European diesel fuel has also improved with regard to environmental and health effects from vehicle/engine exhaust. One important area has been the reduction of the sulphur content. The sulphur limit (10 ppm) is now (since 2009[2]) similar in both EN590 and MK1 fuels, although the actual levels for fuels on the market might be somewhat different. The reduction of the sulphur level enabled the use of more efficient exhaust aftertreatment, such as more active oxidation catalysts and improved particulate filters. A second area of importance is that the content of polycyclic aromatic hydrocarbons (PAH) was limited in EN 590, although the PAH levels are still far lower in the MK1 fuel. It should be noted that the PAH definition in this

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[1] Numbers in bracket designate a reference that is listed in the reference list at the end of this report.
[2] This fuel was made available already in 2005 in smaller quantities on all EU markets.

case is di+ PAH, whereas MK1 fuel specification limits tri+ PAH. Heavier PAH usually have stronger impact on health, although the potency in this respect varies considerably from compound to compound. A most likely side effect of reducing the sulphur content in EN 590 fuel is that the deeper hydrogenation needed to remove sulphur also reduces PAH compounds. Thus, it is likely that the current EN 590 and MK1 fuels are somewhat closer regarding health effects than when MK1 was introduced on the market in the early 1990´s.

The impact of fuel sulphur content on exhaust aftertreatment was mentioned briefly above. However, the most important fact to note is that very few diesel vehicles were equipped with any kind of aftertreatment in the early 1990´s. However, already in the 1992/1993 timeframe − approximately coinciding with the introduction of the Euro 1 emission limits − oxidation catalysts were introduced on most light-duty vehicles. Oxidation catalysts were also available as retrofit kits for heavy-duty vehicles and somewhat later, also diesel particulate filters (DPFs) were introduced on the aftermarket. After the launch of the first successful DPF on a passenger car by Peugeot in 2000, also this technology received a rapid introduction, although a DPF was not necessary to meet the Euro 3/4 emission limits for particulate matter (PM) at that time. The introduction phase of aftertreatment on heavy-duty vehicles and off-road engines has been much longer and also came much later than on light-duty vehicles. All-in-all, aftertreatment devices are used on a much larger share of the vehicle population than in the early 1990´s. Aftertreatment devices are known to substantially reduce the health effects from vehicle exhaust. Thus, it might be speculated that the relative impact of fuel quality on health effects might be less today than when MK1 was first introduced. However, this is the scope of a couple of parallel projects.

Efficiency and CO_2 emissions are becoming more and more important for the transport sector. In view of that development, also the efficiency in fuel production is of great importance. The question about differences between MK1 and EN 590 fuels has also been raised. The first comprehensive study where the fuel production of MK1 diesel fuel was reported was the “Life of fuels” report from Ecotraffic [4]. A few studies have touched upon this topic a couple of times since then but no comprehensive study has been made on MK1 fuel production since then. In contrast, many results have been published on EN 590 diesel fuel and other international fuels of somewhat similar specification. In this context, the knowledge of MK1 fuel production in recent years is limited. First, it should be noted that the Life of fuels is a very old study and conditions have changed considerably since then. Second, the basic data for the Life of fuels study were partly classified and were not published. Thus, it is practically impossible to update this study without the access to new input data.

A couple of the conditions mentioned above led to that the Swedish Government commissioned Trafikverket to conduct a study on MK1 and EN 590 fuels. The work reported here is a small part of this larger study. The present study is totally focussed on CO_2 (and other climate gases) and energy use in a well-to-tank (WTT) perspective of MK1 and EN 590 diesel fuels. It is important to know which fuel is better in these respects and also to quantify the relative difference. These are only two of several aspects of fuel specifications but other aspects are handled in parallel projects.

Scoop of work

As concluded above, the availability of recent data on MK1 fuel production is scarce. Through a framework agreement on consultancy, Ecotraffic was commissioned by Trafikverket to carry out a study of fuel production of MK1 and EN 590 fuels, in close co-operation with oil companies and refineries. As noted above, input data for such a study are not readily available. In addition, in-depth know-how about refinery technology outside the oil companies themselves is limited in Sweden. This is beyond the competence of the main author of this study, although some previous experience from well-to-wheel studies on an overall level has been gained over the years. The competence needed for this task was available through associate professor Börje Gevert at Chalmers University of Technology, who is also involved in Ecotraffic. Gevert provided the scrutinized basic data for fuel production to the WTT calculations.

The very first approach when this work was discussed with Trafikverket was to use the publicly available data from the oil companies, for example for yearly environmental reports from those companies. A kind of “reverse engineering” could be made to calculate missing data. However, the first discussions with the stakeholders, revealed a considerable interest from them to participate in this study and to contribute with the data needed. In two meetings with stakeholders at SPBI[3], the conditions for the study were agreed on and the work was carried on with this as starting point. Eventually, it was found early on in the work that this process was more complicated that first anticipated. Thus, considerable delay in data collection and assessment was the consequence. From one refinery, only calculated data were available, so in this case, no assessment of the calculations and conditions for the basic data was possible to make.

Two basic scenarios were considered:

- Production of MK1 diesel fuel for the Swedish market
- Production of EN 590 diesel fuel for the Swedish market as substitute for the current MK 1 fuel

In the discussions at SPBI during the second meeting, it was noted that contemporary MK1 fuel in some refineries is produced from straight-run distillate, whereas EN 590 fuel is produced using several additional steps. If no MK1 is produced this situation might change somewhat for EN 590, due to the use of the straight-run fraction as blending component. Since the EN 590 fuel is mainly sold on other markets but Sweden, it became apparent that a calculation of efficiency both for Sweden and globally would be necessary to provide the full picture. However, for reporting national emissions and energy use to the EU, OECD and any other body, also the case with emissions and energy use for Sweden must be considered. The oil companies and refineries were asked to amend their data with the necessary information to calculate also global emissions and energy use, which induced a further delay for the project. It was found in one case, that the best way of handling global emissions might have been to expand the system boundaries somewhat by also including some exported fuel oil. However, the effect of this was considered relatively small and within the timeframe and other limitations of the study, it was not possible to make any further investigations of this topic.

[3] SPBI: The Swedish Petroleum and Biofuels Institute (www.spbi.se).

4. Methodology

Overall conditions

The base year for assessment was decided to 2010. The year 2011 was not considered practical due to lagging statistics, considering that the study was initiated in the autumn 2011 and other specific reasons. One refinery had a long shut-down in 2010 due to major overhaul, so in this case, 2009 was considered more representative than 2010. Thus, 2009 was chosen for that refinery. The assessment of time horizon from the oil companies involved implies that the production data for 2010 would be valid approximately until 2015. This is because no major changes and/or investments are planned on this timeframe. Most likely, the conditions would change − to a smaller or larger extent − on the longest time horizon of importance for this study, i.e. 2020-2025. However, it was beyond the scope of this study and certainly not within a reasonable timetable to consider any such changes.

One practical issue discussed with oil companies was that if MK1 would not be produced, some refineries could choose to produce jet fuel rather than diesel fuel, mostly for commercial reasons. Although this could be a plausible option, it was not considered as a scenario in this study. Instead, the only scenario under consideration was that MK1 would be substituted by EN 590.

One of the first important questions raised was whether data from the so-called JEC study, a joint project by the EU and the automotive and oil industry, could be used [5]. There are several reasons for not choosing fuel production data from this report. First, Swedish MK1 fuel is not included in the study. Second, no background data are provided in the JEC report, which makes it practically impossible to use this as basis and to add/change data to represent MK1 fuel production[4]. Third, the JEC study use marginal production approach, which is not applicable in a situation where the total fuel supply to the Swedish market is the topic of the study. In this study, the *total production* rather than the *marginal production* is of primary interest.

Since the conditions for the refineries are not the same and could not become similar even in an imaginary scenario, it was not possible to compare *absolute* results from refinery to refinery. Instead, it was decided to look at the difference between MK1 and EN 590 fuels *at each refinery* and then to weight these results according to the production volumes to obtain weighted average results. The weighting was made on energy basis, i.e. on the total energy content of the produced fuels.

Summer and winter qualities of the EN 590 fuel and, in applicable cases, also for MK1 have been taken into account. Volume weighting has been used to get a yearly average for each refinery.

Any potential change in fuel specification of the base diesel fuels due to FAME (or any other bio-component) blending has been neglected.

[4] The JEC study actually provide only two numbers as results, one for petrol (0,08 MJ/MJ) and the other for diesel fuel (0,10 MJ/MJ). No background data is provided, which makes any additional analysis or use of these data impossible. The results in the JEC study have been obtained via a computer simulation and are not directly bases on actual case studies of refineries, as this study does. It should be noted, though, that the methodology behind the simulation in the JEC is described in considerable detail.

The study has not had any ambition to calculate cost impacts due to the production of various diesel fuel qualities.

Due to reasons of confidentiality, most of the background data and individual results from each refinery cannot be published in this report. This is not the best option for transparency but the commercial aspects for the involved stakeholders simply had to be acknowledged.

Delimitations

As this is not a full well-to-wheel (WTW) study, it is appropriate to discuss the delimitations and system boundaries. Although fuel production is of main interest, the other steps in the WTT chain have also been included to enable researchers in other projects to use the data generated in the present project to get the full WTW picture. Some simplifications have been made in the WTT chain. Simplification with the intent of limiting the extent of the study is one of the obvious reasons but, since the technology used in the refineries and many other conditions are so different, the system boundaries must also be limited. In Figure 1, the WTT chain is illustrated.

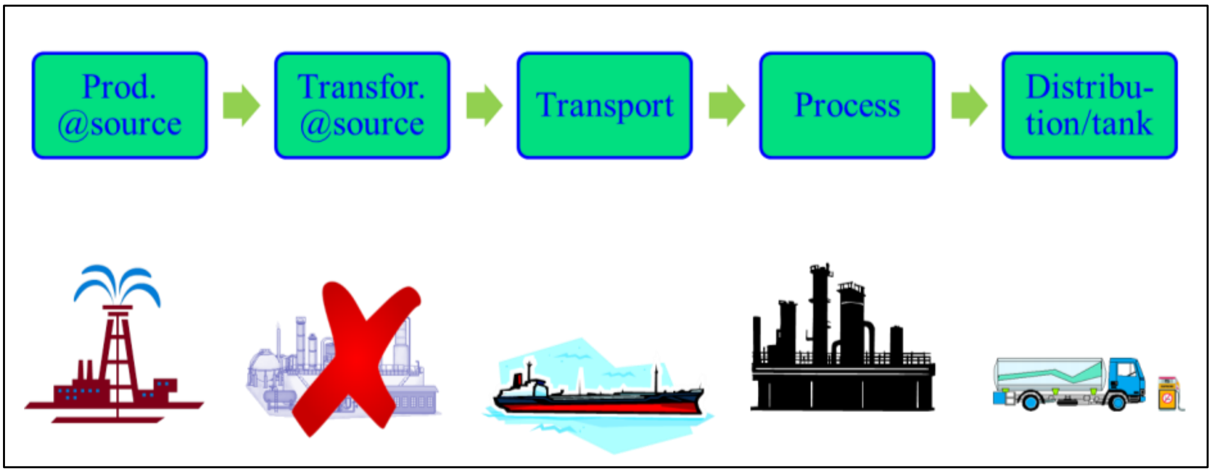

Figure 1. WTT chain

Feedstock production

First, we anticipate that the crude oil is similar for all refineries. Although this is mostly the case, there are differences. In a situation where only EN 590 fuel would be produced, it might be beneficial for some or all of the refineries to change the crude oil basis or blending components somewhat but such options have not been considered here.

Energy use and CO_2 emissions for feedstock production from the JEC study have been used.

Transformation at source

No fuel transformation at the oil well has been considered. Primarily, no transformation of crude oil is made at the source but this might be the case for other feedstocks. As one such example, it could be argued that natural gas transformation to LNG for later use in the refinery could be included and thus, natural gas would be one of the feedstocks at the refinery. However, LNG is no large feedstock at any of the refineries. Where natural gas is used in the refineries (e.g. for heat, steam or H_2 production), it is usually transported by pipeline. For practical reasons and to simplify the analysis, transformation at the resource could be neglected, as indicated in Figure 1 above.

Feedstock transport

Since the same feedstock for all refineries has been anticipated, the fact that crude oil transport distance might differ somewhat has been neglected. In some cases, this would also be counterbalanced by differences in transport distance from the refinery to the market. JEC data for feedstock transport has been used for all refineries.

Fuel production

Carbon capture and sequestration (CCS) – or any other use of CO_2 from the refinery – could be a means of significantly improving the carbon footprint of a refinery and the energy use would also be influenced. However, this technology is not used at any of the refineries today and no immediate plans have been announced either.

Any biomass feedstock that could potentially be used in the refinery (e.g. as process energy, feedstock for hydrogen production or similar), except as blending component in the fuel itself, has been neglected. No such use of biomass is currently under consideration at the refineries.

In the JEC study, European electricity mix is mostly used through the WTW chain (although there are other cases, where other electricity sources are considered). In this study, Nordic electricity mix was used instead for fuel production. This was somewhat of a complication since some refineries have previously considered the actual electricity used in their calculations. To provide some perspective, it could be mentioned that the CO_2 emissions for the Nordic electricity mix was 100 g/kWh in 2010. The corresponding figure in the JEC study was 129 g/kWh.

Some refineries import or export heat and/or steam. First, it was considered to neglect this with the objective to make the conditions as close as possible at each refinery. However, after discussions, it was decided to take this into account. The impact of, for example, export of heat for district heating at some of the refineries has actually a considerable impact on the total energy use and CO_2 emissions. In order for Ecotraffic to assess the validity of the data and results provided by the refineries, data when this import/export has not been taken into account has also been provided by the refineries in question. When heat export is credited, the fuel source substituted is important. It was decided to use natural gas in this calculation as the substitute fuel. The main reason is that this heat is actually replaces natural gas use in most cases. Another reason was that – if some biomass would be replaced, that could be the case to a small extent – this methodology would give no credit for this substitution. The efforts made by the refinery to utilize this energy should be accounted for in the study, although the optimization at the district heat plant might not always be optimal for substituting other resources. For those refineries that export heat, cases with and without export have been analysed. However, only the case with export has been included in this report, simply since this is a reality today.

Fuel distribution

Data from the JEC study has been used for fuel distribution, although this is a rough estimate for our cases. Differences in weight and volume in relation to energy content between the two fuels regarding fuel distribution have been neglected.

Any differences in the use of electricity for fuel storage, dispensing, etc. have been neglected. Thus, the JEC data for fuel transport and refuelling have been used without modification. No consideration for the fact that the electricity in our study for refuelling would come from the Nordic electricity mix and not the EU mix has been neglected. This is simply due to the fact that the energy use for refuelling is extremely low compared to other energy use in fuel distribution and the whole WTT chain, so that such fine tuning is not motivated in this case.

5. Results

Refinery description

A brief description of the five refineries is provided in this section.

Preem refineries in Gothenburg and Lysekil

Preem AB is the largest oil company in Sweden, with refining capacity of more than 18 million m^3 of crude oil per year, i.e. more than the annual use of refined products in Sweden. Preem is the market leader in Sweden in the fields of heating oil and diesel fuel and thus, the company is also the biggest supplier of MK1 diesel fuel on the Swedish market. The two Preem refineries are located in Gothenburg and Lysekil. Both refineries are organized and operated as one joint refinery - Preemraff. About half of the production is exported. Refined products are sold to oil distributors, companies and private individuals in Sweden. Preem's two refineries are among the most modern, environmentally-friendly in Europe and the world.

Continuous investments are made to minimize the environmental impact of the products and the refineries. One example is the refinery in Lysekil, which was recently extended with the latest technology for the production of totally sulfur-free vehicle fuels. The Preem facility at Lysekil is the only refinery in the country with both a catalytic cracker and a hydrocracker. This makes it viable to process crude oils with high sulfur content.

Utilization of the waste heat that is normally cooled off is one way of improving the efficiency at a refinery. This has been done for a long time in the Gothenburg refinery. The data provided in this study showed a substantial impact of waste heat utilization on efficiency.

Statoil, Kalundborg

The Statoil refinery in Kalundborg, Denmark is a small, yet highly efficient refinery. It has a high degree of flexibility, enabling it to produce a variety of products such as gasoline, jet fuel, diesel, propane and fuel oils for markets in Denmark and Sweden. Refined products are also supplied to other markets in Europe, mainly Germany and France while fuel oil is also exported to Italy and the USA. The refinery is connected through two pipelines (gasoline/gasoil) to a terminal at Hedehusene, near Copenhagen.

The Kalundborg refinery is the largest refinery in Denmark and has an annual capacity of close to 5,5 million tonnes of oil products. The oldest part is from 1961 and the refinery has been gradually developed since then. After an expansion in 1995, it can accept a larger proportion of condensate; a feature somewhat unique in comparison to many other refineries. The refinery primarily processes various crude oils and condensates from the North Sea, which are brought in by ship. Since 2002, when the synflex facility was finalised, it has an annual capacity of one million tonnes of sulphur-free (<10 ppm) diesel fuel. Kalundborg cooperates with other local industrial companies over exchanging energy and on commercial exploitation of each other's used coolant water and waste products. Thus the energy efficiency is high, i.e. significant higher than an average refinery in the EU.

St1, Gothenburg

St1 is a modern refinery, which is located in Gothenburg. The annual turnover is approximately 4 million tons of crude oil. Refined products are LPG, jet fuel and diesel fuel and light fuel oil with low sulphur content.

The refinery processes receive their energy mostly from own produced gas. Close to one third of the heat submitted to the production units is recovered and led to the district heating network in Gothenburg, which heats up to 70 000 apartments in Gothenburg. This provides conditions for high energy efficiency.

Neste, Porvoo

Neste Oil has refineries and plants in five countries around the world. Not only petroleum fuels are produced but also the renewable diesel fuel NExBTL. Total production in 2009 was 15,5 million tons, of which 0,2 million tons was the NExBTL renewable diesel fuel. A total of 15,1 million tons of crude oil and other hydrocarbon-based feedstocks were refined, 12,5 million tons at Porvoo and 2,6 million tons at Naantali[5]. The output in 2010 was lower due to a comprehensive maintenance turnaround and after that; the capacity utilization has increased. Due to the turnover, the production in 2009 was considered more representative than 2010, as mentioned already in the previous section.

Due to price differences, the use of Russian crude varies somewhat from year to year. In 2011, a total of 69% of all refinery feedstocks were sourced from Russia. It can be noted that the feedstock used is significantly different than for the other refineries.

According to the Solomon Associates' Energy Intensity Index (EII), the Porvoo refinery was one of the best in the industry. Improved performance was achieved by introducing new liquid catalyst technology for improved performance and conversion rate. Released gas during gasoline loading at the refinery harbour will be recovered after an investment for improving the environment that started construction in 2011. This ensures a cleaner working environment for personnel working at the harbour and reduces the impact on the environment.

Results in a Swedish perspective

The two scenarios here are as previously discussed:

- Production of MK1 diesel fuel for the Swedish market
- Production of EN 590 diesel fuel for the Swedish market as substitute for the current MK1 fuel

In the Swedish perspective, only the energy use and emissions related to the sales of MK1 or EN 590 in Sweden are included. It could be pointed out that a significant part of this energy used and emissions will be outside of Sweden, for example in crude oil recovery.

In Figure 2, the results for energy use and climate gases (in CO_2 equivalents) in the Swedish perspective are shown. The average results have been weighted according to production volumes of fuels sold on the Swedish market. For both energy use and CO_2, "error bars" are shown. These bars actually designate the lowest and highest results in each case; not the standard deviation or any other parameter in statistics.

[5] Swedish speaking people might be more familiar with the Swedish names of these cities, i.e. Borgå and Nådendal.

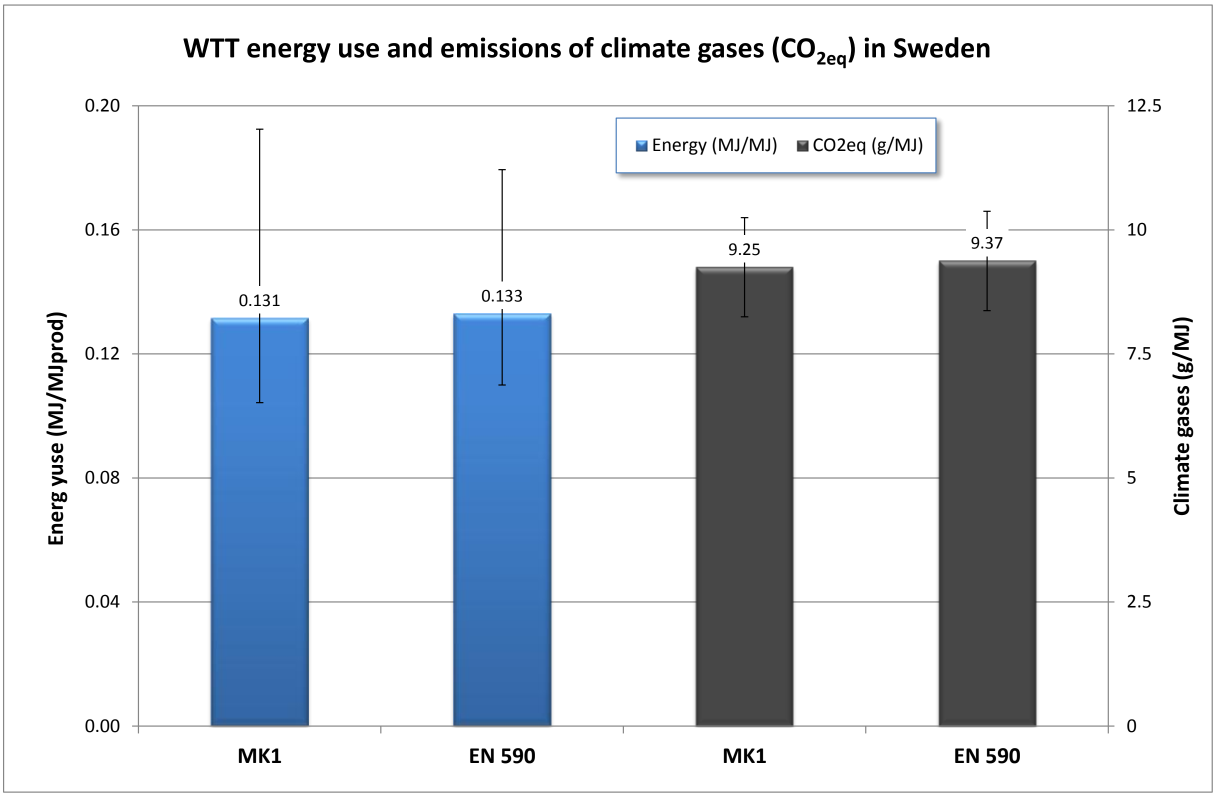

Figure 2. WTT results for energy use and climate gases in a Swedish perspective

The results in Figure 2 show an advantage for MK1 fuel both for energy use and climate gases. However, one should also note that the difference between individual refineries is large, i.e. much larger than the average differences.

There are several reasons for the advantage seen for the MK1 fuel. The main reason is that some refineries use a stream of straight run diesel fuel for MK1 fuel production. For EN 590, cracking is used and this result in more processing to produce this fuel compared to MK1. Additional processing increases energy use and climate gases.

Results in a global perspective

In this section, the results on a global perspective are reported. The two scenarios are the same as in the previous case. The difference here is that the impact on the EN 590 fuel sold in other countries than Sweden is also considered. In other words, if EN 590 production changes when no MK1 fuel is produced, the change in energy use and emissions of climate gases on a global scale is considered.

In Figure 3, the results for energy use and climate gases (in CO_2 equivalents) on the global perspective are shown. Figure 3 is structured in a similar way as Figure 2. Also scaling for the y-axes are the same to easily facilitate direct comparison between the two figures. One clarification might be appropriate: The denotation “MK1 + EN 590” refers to that MK1 fuel is produced for the Swedish market and EN 590 is produced for all other markets. The alternative scenario is, as in the previous case, that EN 590 fuel is produced for all markets.

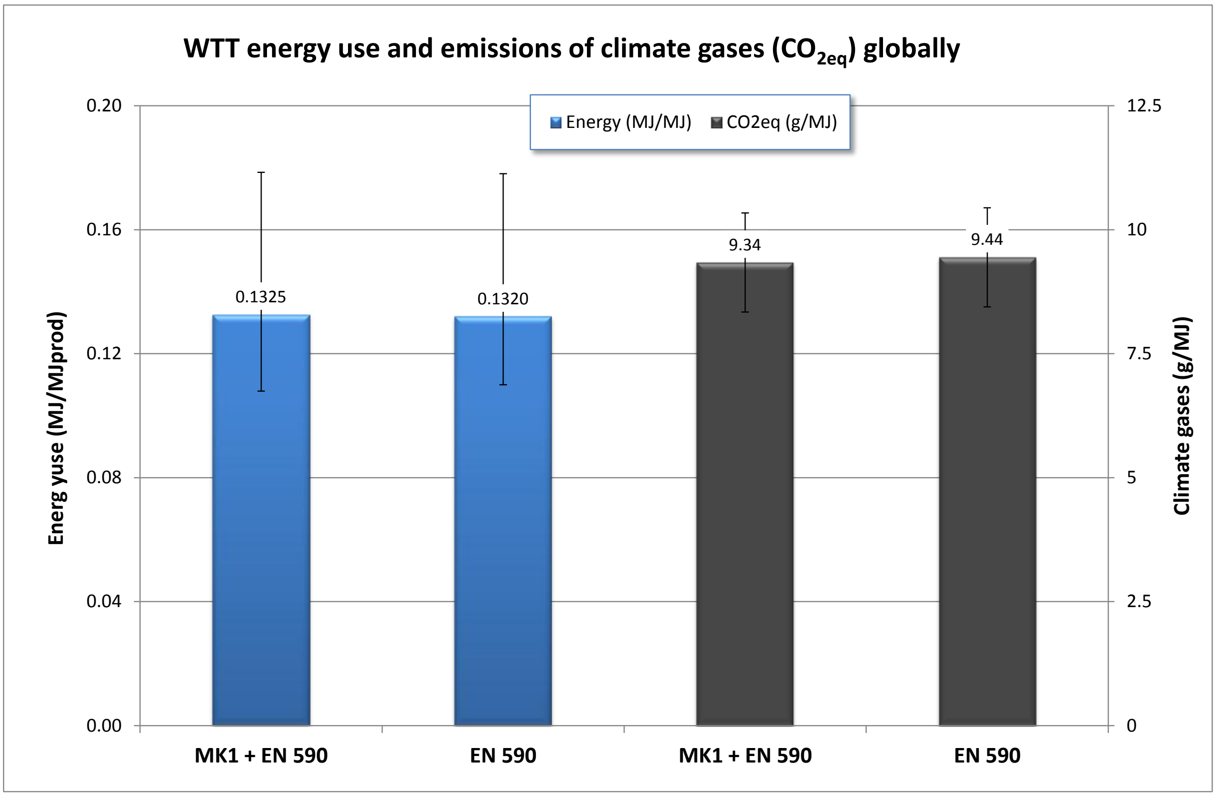

Figure 3. WTT results for energy use and climate gases in a global perspective

The results in Figure 3 show a negligible difference between both energy use and climate gases for both scenarios on the global perspective. Note that the difference for energy use and emissions of climate gases is negligible (energy) or small (climate gases) for EN 590 in this case compared to the previous case (Figure 2).

The main reason for the negligible difference in this case is that the straight run stream that in some refineries is used for producing MK1 fuel is now blended in the whole EN 590 fuel pool. Thus, the EN 590 fuel is “improved” regarding energy use and the emission of climate gases compared to EN 590 production when MK1 fuel is also produced.

6. Discussions and conclusions

Discussion

A general comment of great importance is that the basic data submitted by the refineries and oil companies has been treated with confidentiality. Therefore, any detailed discussion about data, calculations and many other topics cannot be conducted. Some details we have been able to discuss directly with the refineries involved but most of these discussions cannot be documented here.

With the limitations mentioned above, the discussion and conclusions below is rather brief. It has mostly been limited to methodology and general comments.

Prior to the work carried out in this study, we had generally anticipated somewhat higher energy use and emissions of climate gases for MK1 production in comparison to EN 590 production, simply due to the additional processing of the fuel that must be done in MK1 production compared to the case for EN 590. This was not the outcome. There are several reasons for this somewhat confounding result but one in particular could be highlighted. It became apparent to us in scrutinizing the basic data that any refinery, regardless if MK1 or EN 590 is the main product, has optimized their production for that particular fuel. Thus, although we have significant differences between MK1 and EN 590 production – i.e. higher in some cases and lower in some cases – these differences tend to cancel out when we weigh the results together. One other general observation is that utilization of waste heat, whenever applied, tends to somewhat reduce the difference between fuels, i.e. a lower efficiency gives more waste heat but this since this is utilized, the relative difference is reduced.

Differences between refineries

The apparently large difference between the refineries is a topic for discussion. First, it should be noted that the conditions differ between the refineries and this definitely one cause for the differences seen. For example, not all refineries can export waste heat for district heating. This has a decisive impact on energy use in the refineries where this can be utilized. There are also other differences between refineries that cannot be taken into account. Second, one important factor is how the hydrogen used for cracking, desulphurisation and de-aromatization is treated in the calculations. This is a very difficult question. The JEC study also touched upon this topic but did not provide many guidelines or any specific information as to how they solved this problem (WTT, Appendix 3 [5]). This issue was discussed thoroughly at the last meeting at SPBI and it was decided to make a revision of the report (actually this is rev. No. 2, since rev. No. 1 was used only internally) where new data on hydrogen production were taken into account. This delayed the final version of the report but was considered essential against the basic data that were available at that time and the assessment of those data.

Most of the hydrogen used in diesel production originates from petrol production. Hydrogen is actually a by-product from petrol reformation, a process used to increase octane number. It the past, it was common that surplus hydrogen was used as process fuel in the refinery. With increasing demand for diesel fuel and more stringent diesel fuel standards, the demand for hydrogen has increased to a point that there is a deficiency of hydrogen in many cases. Natural gas or LPG can be used as a source for supplemental hydrogen. Hydrogen is also used for other purposes than diesel production, e.g. hydrocracking. Various streams of hydrogen might be used for different applications but it could be considered appropriate to "pool" hydrogen from various sources in the calculation, although actual physical pooling is not made in practice. For the hydrogen that originates from petrol production, the allocation of energy use and climate gases is difficult. Furthermore, the energy content per kg or volume of the hydrogen raw gas is very much different from any other stream in the refinery. The best would probably be to do the allocation on energy content. Where basic data on fuel production was available (three refineries), there seem to be differences in how hydrogen was treated in the calculations. A general conclusion at the last meeting at SPBI was that if system boundaries had been expanded to also include petrol, the result for the diesel fuel would most likely have been somewhat different. Therefore, refineries were asked to have a second look at their data and new results were submitted to us in the beginning of June. In some cases, new data according to the new guidelines outlined above were calculated by Börje Gevert. From the results where we have basic data, we can conclude that the basis for comparison has improved although the treatment of hydrogen is still not exactly the same in all cases. In one case, it was not possible to carry out a new calculation on emissions of climate gases due to lack of basic data for carrying out this calculation. All in all, the results presented here seem to be the best that can be done under the current conditions. Since the results from some refineries increased and some decreased with the new data, no significant differences in the weighted results were the outcome of this analysis.

Comparison with the JEC study

As noted several times in this report, all refineries in the Nordic countries are highly energy-efficient compared to European average. This conclusion is also valid in comparison to the benchmark by the engineering company Solomon Associates (Energy Intensity Index, EII), where these refineries score high. This is most likely a general explanation as to why the differences between the two diesel fuel qualities are relatively small in this report.

In Figure 4, the results for specific energy use in fuel production from the JEC study are shown.

Recall that the scope of the JEC study was to look at *marginal* fuel production. Furthermore, the results in Figure 4 do not include the steps in WTT *before* and *after* the production stage, so a direct comparison with results Figure 2 and Figure 3 should not be made. Eventually, an energy use of 0,10 MJ/MJ in the JEC study is much higher than the refineries assessed in the present study. The corresponding figure for weighted energy average for the EN 590 fuel is about 0,04 MJ/MJ in our case; regardless if it is on a Swedish or global perspective. This again underlines the high efficiency of the Nordic refineries.

A similar figure as Figure 4 was also shown for climate gases in the JEC report. Since this figure looks essentially the same as Figure 4 (except for the scale on the y-axis), it has been omitted here. The emissions of climate gases were 8,6 g CO_2 equivalent per MJ fuel produced in the JEC report. The corresponding number in the present study is rounded to 2,4 g CO_2 equivalent per MJ fuel produced in both cases, with a marginally higher level when EN 590 substitutes MK1. The relative difference in comparison to the JEC study is even greater than for energy.

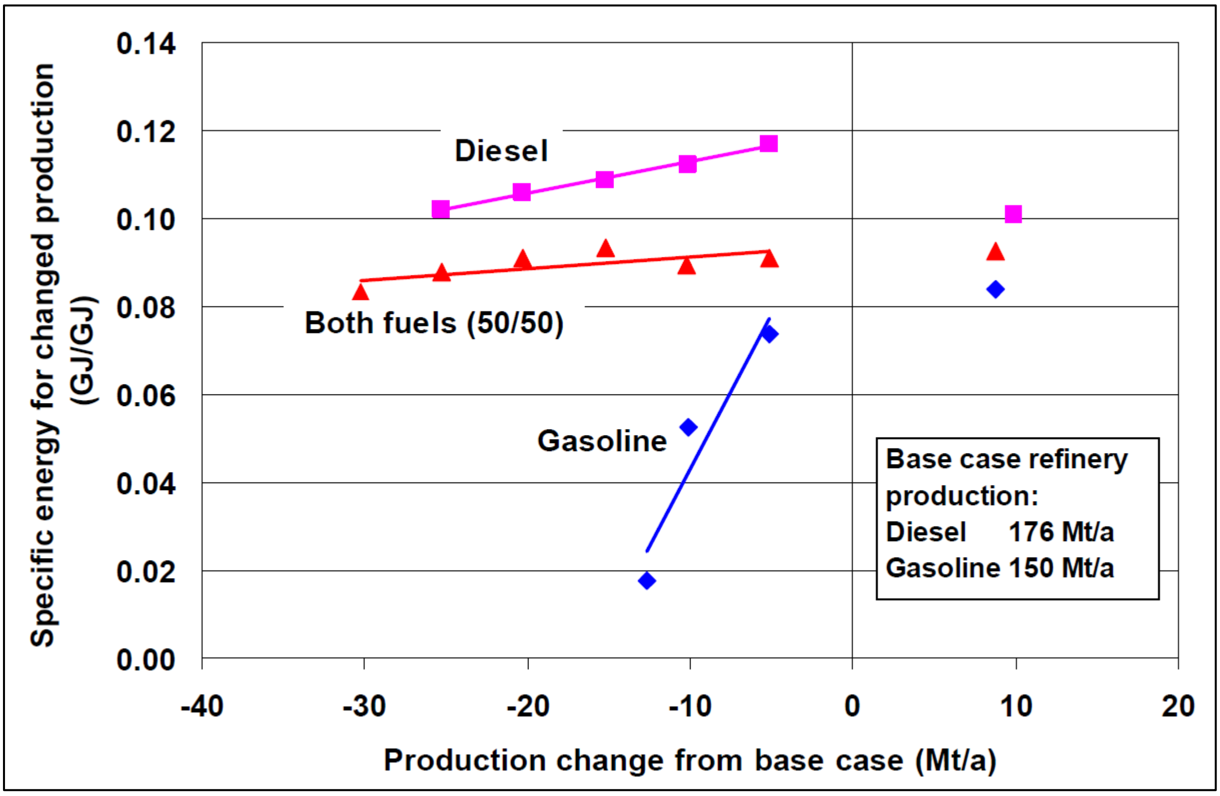

Figure 4. JEC results for specific energy use in diesel and gasoline production

Implications for WTW analysis

It should be noted that the WTT calculations do not take the carbon content of the fuel into account. Per definition, the CO_2 emissions from the vehicle are attributed to the tank-to-wheel (TTW) stage of the WTW chain. Thus, the carbon content of the fuel will also have an impact at the TTW stage. Compared on energy basis, MK1 fuel contains roughly 1 % less carbon than EN 590 fuel. Given that the energy use in the vehicle would be the same, this would give another advantage of ~1 % at the TTW stage for MK1 diesel fuel. If the energy efficiency, for some reason (which is not very likely), would be different for the two fuels, the difference might change. CO_2 emissions have been measured directly in vehicle/engine exhaust in the parallel projects to the present one and these might give an answer to this question. Note also that measurements of fuel consumption on chassis dynamometer tests are normally made via analysis of exhaust emissions. On engine dynamometers, where also gravimetric measurements of fuel consumption are carried out, a carbon balance is made to validate the results.

The difference in carbon content of the two fuels should also be discussed. It is not necessary fully correct to make calculations on the actual carbon content of the various products produced in the refinery. For example, carbon content in two fuels might vary although the energy efficiency is the same. An alternative approach might be to look at the refinery process as follows:

1. The input to the refinery (crude oil) contains a certain number of carbon atoms and a certain amount of energy.
2. Carbon is "lost" in the processing and energy is "wasted", so that the products produce contain less of each than the input.
3. Various products are produced at certain efficiency and these products contain a certain number of carbon atoms per energy unit. Instead of using this carbon content for

each product as normally done, a carbon content obtained by some kind of allocation could be used.

To our knowledge, the alternative approach mentioned above has not been documented in any public domain literature. Given the relatively small difference between the two fuel qualities, it is not likely than an alternative approach would give much different results.

Conclusions

The scope of this study was to evaluate the energy use and emissions of climate gases in a well-to-tank perspective for two diesel fuel qualities, MK1 and EN 590. The timeframe chosen was 2010 but in one case, the year 2009 was considered more representative than 2010. The results for the base years should be valid until approximately 2015. The conditions for the study were decided jointly with the stakeholders during two meetings at SPBI.

The following general conclusions can be drawn:

- The work and timeframe for collecting basic data for the study by the refineries was substantially underestimated.
- In order to assess data and calculations in refineries, in-depth knowledge about refinery processes normally not possessed by experts in LCA and WTW fields is needed. This expertise was available at the Chalmers University of Technology.
- There are differences for the system boundaries and methodology between the refineries that we have not been able to fully take into account.
- The differences in specification between MK1 and EN 590 fuels have been somewhat reduced over the years, which has most likely also narrowed the gap in production between the two fuels compared to the situation in the past.
- During the work it was apparent that, besides the two scenarios set up before the study (production of MK1 or EN 590 for the Swedish market), it was also necessary to evaluate energy use and climate gases both in a Swedish and global perspective.
- Weighting of the results from each refinery has been made according to the production volume on energy base.
- In the Swedish perspective, MK1 diesel fuel has a small advantage for both energy use and climate gases.
- In the global perspective, there is practically no difference in energy use and climate gases between the two fuel qualities.
- Due to reasons of confidentiality, no in-depth discussion about single refineries can be carried out in the present report.
- The differences in results between the refineries are substantial and the difference in relative terms is greatest for energy use. The gap between the highest and lowest refineries is much greater than the weighted average difference between the two fuels.
- One of the greatest differences between data from the refineries seems to be how hydrogen is treated in the calculations. An attempt to take this into account by expanding the system boundaries to include also petrol was made. In addition, all hydrogen produced was treated as a pool. New data were submitted by some refineries and new calculations were made by us for others. However, the total weighted results did not change very much due to that increases for some refineries and decreases for others. More work should be carried out in this area.

- Prior to this work, we had generally anticipated somewhat higher energy use and emissions of climate gases for MK1 production in comparison to EN 590 production, simply due to the additional processing of the fuel in the MK1 case. However, it became apparent by scrutinizing the basic data that any refinery, regardless if MK1 or EN 590 is the main product, has optimized their production for that particular fuel. Thus, although we have significant differences between MK1 and EN 590 production – i.e. higher in some cases and lower in some cases – these differences tend to cancel out when we weigh the results together.
- Compared to average European refineries, the JEC study and Solomon data, the five refineries in the Nordic countries have higher efficiency and lower emissions of climate gases.
- This study provides data from the WTT step that, with TTW data from other studies, enables the calculation of full WTW energy use and emissions for the two diesel fuel qualities studied.

A final remark in this report might be that since the differences in energy use and emissions of climate gases between the two fuel qualities are relatively small, perhaps other parameters should be the basis for a decision about which one of the two fuel qualities to promote.

7. Acknowledgements

The involved stakeholders, i.e. oil distributing companies (SPBI members) and their refineries in Sweden as well as diesel fuel suppliers/refiners abroad, are acknowledged for contributing with basic data for this study.

SPBI is acknowledged for hosting meetings in this project in three occasions and for valuable input during these discussions.

Associate professor Börje Gevert (Chalmers and Ecotraffic) is acknowledged for compiling the basic data received from the stakeholders and for scrutinizing the base data. Gevert is also acknowledged for his help in interpreting the results and preparing this report.

Magnus Lindgren at Trafikverket is acknowledged for valuable input during the discussions held within the framework of this project.

This study was funded by Trafikverket.

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PREEM AB
Certificate of Quality

Product Code:	**SD-DIESEL EUR VI B7**	Vessel:	
Nomination number:	**FAT.111108.SDEUROVIB7**	Destination:	
Lineblend:		Account:	
Tank:	**FAT**	Delivery Date:	**2011-11-08**
Revised Issue:		Sample Number:	**2011029188**

Diesel Euro VI B7

Properties	Results	Units	Ref. Test Methods
Appearance at 20°C	BRIGHT AND CLEAR		Visual inspection
Aromatic content	18,4	% m/m	EN 12916:2006
Aromatic content	15,6	% V/V	EN 12916:2006
Ash content	< 0,010	% m/m	SS-EN ISO 6245:2003
Carbon content	86,0	% m/m	ASTM D 5291-10
Carbon Hydrogen Ratio	6,32		ASTM D 5291-10
Carbon Oxygen Ratio	118,10		ASTM D 5291-10
Carbon residue (on 10% dist res)	< 0,20	% m/m	SS-EN ISO 10370:1996
Cetane index	47,7	-	SS-EN ISO 4264:2007
Cetane number	52,3		SS-EN ISO 5165:1998
Cloud point	-11	°C	SS-EN 23015:1994
Cold Filter Plugging Point	-21	°C	SS-EN 116:1999
Colour	Undyed		Visual inspection
Copper content	< 1	mg/kg	ASTM D 6443:2010
Cu strip corrosion (3h at 50°C)	1A		SS-EN ISO 2160:1998
Density at 15°C	840,3	kg/m3	SS-EN ISO 12185 T1:99
Dist: IBP	173,5	°C	SS-EN ISO 3405:2000
Dist: Temp. at 10% V/V rec.	199,9	°C	SS-EN ISO 3405:2000
Dist: Temp. at 50% V/V rec.	256,0	°C	SS-EN ISO 3405:2000
Dist: Temp. at 90% V/V rec.	331,1	°C	SS-EN ISO 3405:2000
Dist: Temp. at 95% V/V rec.	344,6	°C	SS-EN ISO 3405:2000
Dist:FBP	354,6	°C	SS-EN ISO 3405:2000
Dist:Residue	1,0	% V/V	SS-EN ISO 3405:2000
FAME content	6,5	% V/V	SS-EN 14078:2009
Flash point	61,0	°C	SS-EN ISO 2719:2003
Hydrogen content	13,6	% m/m	ASTM D 5291-10
Lubricity (WSD 1.4) at 60°C	< 400	µm	SS-EN ISO 12156-1:06
Net heat of combustion	42,59	MJ/kg	SS 15 51 38:1992
Oxidation stability	< 25	g/m3	SS-EN ISO 12205:1996
Oxidation stability at 110°C	46,0	hours	EN 15751:2009
Oxygen content	0,7	% m/m	ASTM D 5291-10
Polycyclic aromatic content	4,7	% m/m	EN 12916:2006
Strong acid number SAN	< 0,10	mg KOH/g	ASTM D 974-04
Sulphur content	4	mg/kg	SS-EN ISO 20846:2004
Total contamination	< 20	mg/kg	SS-EN 12662:2008
Water content	65	mg/kg	SS-EN ISO 12937:2001
Viscosity at 40°C	2,462	mm2/s	SS-EN ISO 3104/AC:99

Results according to ISO 4259

This product meets the quality requirements according to customer's nomination.

Work by: Dolores Martinez

Chemist in Charge:

Telephone: +46 (0)10 450 41 85

Fax: +46 (0)10 450 41 86

For Preemraff Göteborg: Dolores Martinez

Appendix 2

PREEM AB
Certificate of Quality

Product Code:	**SD-DIESEL EUR VI B7**	Vessel:	
Nomination number:	**FAT.111114.B7**	Destination:	
Lineblend:		Account:	
Tank:	**DBB7 från OKQ8**	Delivery Date:	
Revised Issue:	**Andrad från prov nr. 2011029238**	Sample Number:	**2012007318**

Diesel Euro VI B7

Properties	Results	Units	Ref. Test Methods
Appearance at 20°C	BRIGHT AND CLEAR		Visual inspection
Aromatic content	4,0	% V/V	EN 12916:2006
Ash content	< 0,010 *	% m/m	SS-EN ISO 6245:2003
Carbon content	85,0	% m/m	ASTM D 5291-10
Carbon Hydrogen Ratio	5,97		ASTM D 5291-10
Carbon Oxygen Ratio	115,10		ASTM D 5291-10
Carbon residue (on 10% dist res)	< 0,20 *	% m/m	SS-EN ISO 10370:1996
Cetane index	52,5	-	SS-EN ISO 4264:2007
Cetane number	56,0		SS-EN ISO 5165:1998
Cloud point	-30	°C	SS-EN 23015:1994
Cold Filter Plugging Point	-40	°C	SS-EN 116:1999
Colour	Undyed		Visual inspection
Copper content	< 1	mg/kg	ASTM D 6443:2010
Cu strip corrosion (3h at 50°C)	1A *		SS-EN ISO 2160:1998
Density at 15°C	819,5	kg/m3	SS-EN ISO 12185 T1:99
Dist: IBP	179,9	°C	SS-EN ISO 3405:2000
Dist: Temp. at 10% V/V rec.	208,6	°C	SS-EN ISO 3405:2000
Dist: Temp. at 50% V/V rec.	239,3	°C	SS-EN ISO 3405:2000
Dist: Temp. at 90% V/V rec.	295,2	°C	SS-EN ISO 3405:2000
Dist: Temp. at 95% V/V rec.	314,4	°C	SS-EN ISO 3405:2000
Dist:FBP	326,0	°C	SS-EN ISO 3405:2000
Dist:Residue	1,0	% V/V	SS-EN ISO 3405:2000
FAME content	6,9	% V/V	SS-EN 14078:2009
Flash point	67,5	°C	SS-EN ISO 2719:2003
Hydrogen content	14,3	% m/m	ASTM D 5291-10
Lubricity (WSD 1.4) at 60°C	188	µm	SS-EN ISO 12156-1:06
Net heat of combustion	42,75	MJ/kg	SS 15 51 38:1992
Oxidation stability	< 25	g/m3	SS-EN ISO 12205:1996
Oxidation stability at 110°C	> 20,0	hours	EN 15751:2009
Oxygen content	0,7	% m/m	ASTM D 5291-10
Polycyclic aromatic content	0,3	% m/m	EN 12916:2006
Strong acid number SAN	< 0,10	mg KOH/g	ASTM D 974-04
Sulphur content	< 3	mg/kg	SS-EN ISO 20846:2004
Total contamination	< 24 *	mg/kg	SS-EN 12662:2008
Water content	< 30	mg/kg	SS-EN ISO 12937:2001
Viscosity at 40°C	2,140	mm2/s	SS-EN ISO 3104/AC:99
Zinc content	< 1	mg/kg	ASTM D 6443:2010

* Värderna kommer från Prod Spec. Diesel D15RSE OKQ8 027/07 (MK1)

Results according to ISO 4259

This product meets the quality requirements according to customer's nomination.

Work by: Dolores Martinez

Chemist in Charge:

Telephone: +46 (0)10 450 41 85

Fax: +46 (0)10 450 41 86

For Preemraff Göteborg: Dolores Martinez

Summary of other steps than production in the WTT chain

Most of the basic data in this report originate from the five refineries. However, to get a complete picture of the WTT chain, other steps in the WTT chain must also be included. Data for this calculation has been obtained from the JEC report [5]. This is not thoroughly documented in the JEC report but these data are available in the MS Excel sheets that can be downloaded from the same site as the mentioned report.

In response to a question from representatives of one of the refineries, a summary of the calculation is shown in Table A3.1 below. The table shows the energy use in the whole WTT chain per each distinctive stage, the accumulated energy use stage-by-stage and the relative contribution to the total energy use from each stage. Starting from the final stage in the WTT chain (distribution), the energy content of the product handled in each stage upstream is higher than in the final stage. Thus, a simple summary of the energy use per stage for the whole WTT chain (0,188) does not yield a correct result. Instead, the loss per stage has to take into account that the energy handled upstream is more than 1 MJ and this gives a total energy use of 0,198 MJ/MJ. For example, we no longer have 1 MJ in the stage above distribution (depot) but 1,014 MJ instead, as indicated in the column for accumulated energy. A calculation of the relative contribution for each stage to the total energy use has been added in the column to the right. Evidently, the relative contribution to the total energy use, if exemplified by crude oil production (0,066), is greater than the energy use for this stage when it is treated separately (0,058).

Table A3.1 Contribution to energy use from various stages in the WTT chain

WTT stage	Per stage (MJ/MJ	Accum. (MJ/MJ)	Contribution (MJ/MJ)
Crude oil production	0.058	1.198	0.066
Crude oil transportation	0.011	1.133	0.012
Marginal diesel refining	0.10	1.120	0.102
Diesel transport	0.0023	1.019	0.002
Diesel depot	0.0024	1.016	0.002
Diesel distribution	0.014	1.014	0.014
Summary	**0.188**	**n.a.**	**0.198**

Similar to the calculation above, a calculation of the emissions of climate gases has to be carried out using the same principles but this example is omitted here.