Consequences on emissions and air quality of change in vapour pressure of gasoline

Scientific note from DCE – Danish Centre for Environment and Energy

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Data sheet

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Authors:	Marlene S. Plejdrup, Morten Winther & Thomas Ellermann
Institution:	Department of Environmental Science, Aarhus University
Referee:	Ole-Kenneth Nielsen
Quality assurance, DCE:	Vibeke Vestergaard Nielsen
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1. Background

The Danish Environmental Protection Agency has requested DCE to provide input on the consequences on air quality and emissions of sale in the summer months of gasoline with a vapour pressure of 70 kPa. More specifically DCE has been asked to assess the consequences on NMVOC emissions, and ambient air concentrations of ozone and benzene with a vapour pressure for gasoline of 70 kPa in June, July and August instead of 60 kPa.

As the latest year of official statistics is 2018, this has been used as a basis for the calculation of the impact on NMVOC emissions.

2. Impacts on NMVOC emissions of a higher vapour pressure

The vapour pressure of gasoline affects the emissions of NMVOC through evaporation from tanks from large storage tanks, filling stations and road transport vehicles. The Danish inventory follows the methodologies provided in the EMEP/EEA Guidebook (EEA, 2019). The Guidebook distinguishes between the emissions from storage/distribution and the emissions from road transport vehicles and therefore the impact is described separately below. In the official reporting template, the relevant categories in the Nomenclature For Reporting (NFR) are 1A3bv Road transport: Gasoline evaporation and 1B2av Distribution of oil products.

2.1 1A3bv Road transport: Gasoline evaporation

Evaporative emissions of hydrocarbons from road transport vehicles originates from hot and warm running losses, hot and warm soak loss and diurnal emissions from the gasoline tank. The calculations follow the Tier 2 approach documented in the EMEP/EEA Guidebook (2019). The basic evaporative emission factors provided by EMEP/EEA (2019) are season related (split into four ambient temperature intervals and associated RVP's).

For Danish climate conditions evaporative factors for the temperature intervals [-5, 10], [0, 15] and [10, 25] ^{o}C are used. The latter temperature interval represent Danish ambient summer temperatures, and hence the associated evaporative factors (valid for RVP = 70 kPa, c.f. EMEP/EEA (2019)) is used to calculate the evaporative emissions during the summer months June, July and August. The evaporative emission factors are shown in more details in the EMEP/EEA Guidebook (2019).

Running loss emissions originate from gasoline vapour generated in the fuel tank while the vehicle is running. The distinction between hot and warm running loss emissions depends on engine temperature, i.e. the engine being either hot or cold. The emissions are calculated as annual mileage (broken down into cold and hot mileage totals using the β-factor) times the respective emission factors. For vehicles equipped with evaporation control (catalyst cars) only hot running loss emissions occur. The running loss emissions are calculated as:

$$E^{R}_{j,y} = N_{j,y} \cdot \frac{M_{j,y}}{l_{trip}} \cdot ((1-\beta) \cdot HR + \beta \cdot WR) \qquad (1)$$

Where E^R is running loss emissions, l_{trip} = the average trip length, and HR and WR are the hot and warm running loss emission factors, respectively.

Hot and warm soak emissions also occur for carburettor vehicles (no evaporation control), whereas for catalyst cars (evaporation control) only hot soak emissions occur. The soak emissions are calculated as number of trips (broken down into cold and hot trip numbers using the β-factor) times respective emission factors:

$$E^{S}_{j,y} = N_{j,y} \cdot \frac{M_{j,y}}{l_{trip}} \cdot ((1-\beta) \cdot HS + \beta \cdot WS) \qquad (11)$$

Where E^S is the soak emission, l_{trip} = the average trip length, and HS and WS are the hot and warm soak emission factors, respectively.

Average maximum and minimum temperatures per month are used in combination with diurnal emission factors to estimate the diurnal emissions from both carburettor and catalyst vehicles E^d:

$$E_{j,y}^{D} = 365 \cdot N_{j,y} \cdot e^{D} \tag{12}$$

Each year's total is the sum of each layer's running loss, soak loss and diurnal emissions.

Figure 1 shows the total evaporative emissions from Danish road transport from 1990 to 2018. The emissions decline by 92 % from 1990 to 2018, mainly due to the gradually phasing in of catalyst vehicles equipped with more efficient evaporation control technologies.

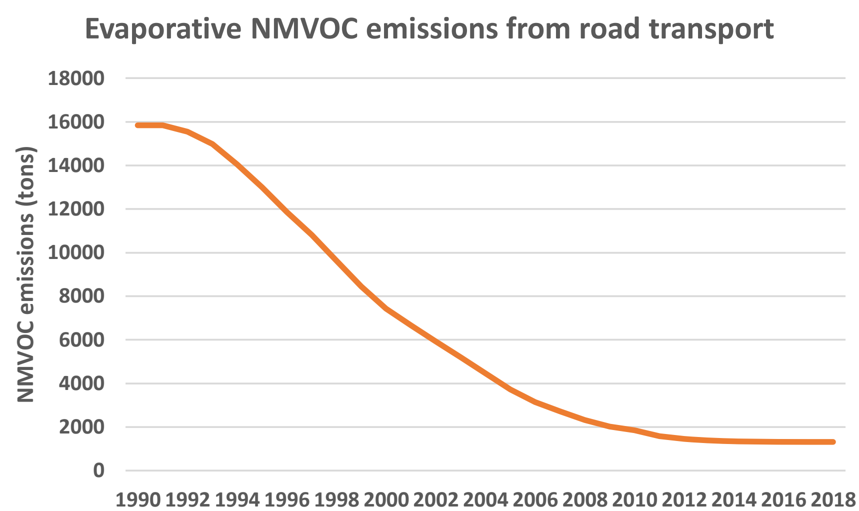

Figure 1. Evaporative NMVOC emissions from road transport for the years 1990-2018.

In 2018, the calculated evaporative NMVOC emissions from road transport are estimated to 1322 tons. This corresponds to 1.11 % of the national total NMVOC emissions in 2018 (119.67 kt).

2.1.1 Impact analysis

The evaporative emission factors presented in EMEP/EEA (2019) do not include RVP and ambient temperature as independent variables. Hence, it is not possible directly to estimate the increase in the evaporative emissions by changing the gasoline RVP from 60 kPa to 70 kPa during the summer months June, July and August.

Instead a scenario is considered in which the evaporative emissions for the summer months reported for Denmark in 2018 and based on RVP = 70 kPa, are assumed to be twice as high as the emission estimate based on RVP = 60 kPa evaporative factors (RVP60 Scenario)[1].

Table 1 shows the evaporative NMVOC emissions reported for Denmark in 2018 (2018 National total), and for the RVP60 Scenario. The results are shown for 2018 as a total and as a sum for the summer months June, July and August.

Table 1. Evaporative NMVOC emissions reported for Denmark in 2018 (2018 National total), and for the RVP60 Scenario.

Case	RVP summer months kPa	DK Summer months NMVOC (tons)	DK Year total NMVOC (tons)
Baseline (2018 National total)	70	413	1322
RVP60 Scenario (50 % summer reduction)	60	206	1116
Emission difference (Baseline minus RVP60)		206	206

In the baseline case, the share of evaporative emissions during the summer months are 31 % of the total evaporative emissions for road transport in 2018. In Scenario 1, this emission share becomes 18 %, and the NMVOC emissions savings become 206 tons.

As previously explained, the total road transport evaporative emissions correspond to 1.11 % of the national NMVOC emissions in 2018, and for the summer emissions alone the emission share becomes 0.34 %.

In Scenario 1, the total road transport evaporative emissions amount to 0.93 % of the national NMVOC emissions, and the emission share for the summer months becomes 0.17 %.

2.2 1B2av Distribution of oil products

The current method used for calculating NMVOC emissions from Distribution of oil products is based on the EMEP/EEA Guidebook (2019). The sector include emissions from storage tank filling and automobile refuelling.

Activity data are annual sold amounts of gasoline from the Energy statistics published by the Danish Energy Agency. The emission factors are based on the Guidebook, expressed as functions that depend on e.g. vapour pressure (RVP) and ambient temperature (T). The present method use annual mean values for vapour pressure and ambient temperature, and annual total gasoline sales. The average vapour pressure used is 82.5 kPa and the average annual ambient temperature used is 7.7°C.

The NMVOC emissions reported for distribution of oil products in the latest submission (February 2020) are shown in Figure 2 for the time-series 1990-

[1] To establish the RVP60 Scenario, RVP60 and RVP70 emission sensitivity calculations were made on a Tier 3 level with a previous version of the European COPERT model – COPERT 3. The emission results for RVP70 based evaporative emission factors in June, July and August became 25 % higher than those results obtained by using RVP60 based factors. A 50 % emission reduction margin chosen in the present study when shifting from RVP = 70 kPa to 60 kPa is regarded as a safe distance margin to encompass eventual emission uncertainties which cannot be quantified.

2018. The NMVOC emissions shows a significant decrease from 1990 to 1994 due to implementation of abatement technologies. The NMVOC emissions in 2018 is 713 ton. This corresponds to 0.6 % of the national total NMVOC emissions in 2018 (119.67 kt)

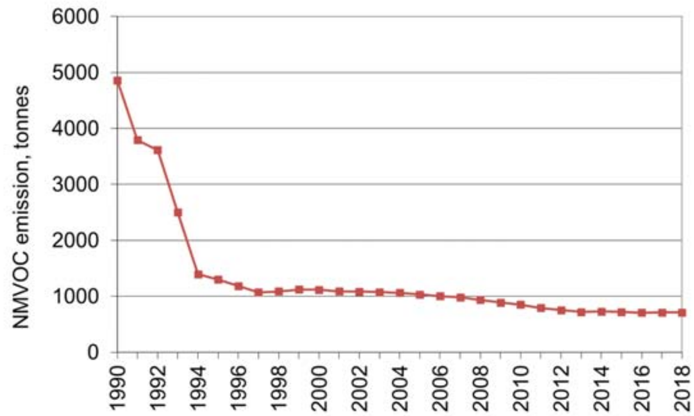

Figure 2 NMVOC emissions from distribution of oil products for the years 1990-2018.

2.2.1 Impact analysis

The present emission calculation method does not take into account monthly variations. However, it is possible to estimate the impact of changing the vapour pressure from 60 kPa to 70 kPa for the summer months June, July and August. The estimate is based on the preliminary 1991-2020 standard climate normal from the Danish Meteorological Institute (DMI); June 14.5 °C and July and August 16.9 °C. The results from the impact analysis in shown in Table 2. The total impact on the annual emissions by a change from 60 kPa to 70 kPa in the summer months June-August is 29 tonnes NMVOC. This is not possible to reflect with the current methodology, as this is based on an annual mean RVP that is higher than 70 kPa. The impact of changing summer vapour pressure correspond to around 4 % of the NMVOC emissions from distribution of oil products in 2018. Further, the impact correspond to 0.02 % of the national total NMVOC emissions in 2018..

Table 2. Impact analysis of change from 60 kPa to 70 kPa for the summer months June-August.

	RVP	T	June	July	August	Sum
Baseline	82.5	All months 7.7 °C	59	59	59	178
Scenario 1	70	Jun 14.5°C, Jul & Aug 16.9°C	62	67	67	195
Scenario 2	60	Jun 14.5°C, Jul & Aug 16.9°C	53	57	57	166
Difference (Sc1-Sc2)			*9*	*10*	*10*	*29*

3. Status of air quality of ozone in Denmark and the potential impact of the dispensation on ozone levels in Denmark

Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe specifies target values for the air quality of ozone in order to protect human health and vegetation. Moreover, the directive requires that Member States shall take measures to ensure that a plan or programme is prepared and implemented in order to attain the health and vegetation based target values that entered into force by the year 2010.

The target value for ozone defines that 120 $\mu g/m^3$ must not be exceeded more than 25 times during a calendar year. In 2018, the concentrations of ozone (maximum daily 8 hour mean value) exceeded 120 $\mu g/m^3$ 16 times at the measurement station with the highest number of exceedances (Ellermann et al., 2020). Hence, there were no exceedances of this target value in 2018.The target value has never been exceeded in Denmark. The long-term objective defines that the maximum daily 8 hour mean values must not be exceeded during a calendar year. This target were exceeded at most of the measurement stations (Ellermann et al., 2020). However, this target value has not entered into force and the date for entry into force has not been settled yet. This shows that the ozone concentration in Denmark is well below the target value in the directive even though we still have a few exceedances of the long term target value. The exceedances are due to long-range transportation of ozone from countries south of Denmark.

The information threshold of ozone (180 $\mu g/m^3$) was not exceeded in 2018 (Ellermann et al., 2020). The information threshold is typically exceeded once a year for every two to three years. The alert threshold (240 $\mu g/m^3$) has never been exceeded.

The EU directive includes also a target value for protection of the vegetation against ozone. This target specifies that the AOT40 (Accumulated Ozone exposure over a Threshold of 40 ppb) value must not exceed 9000 ppb·hours (=18000 $\mu g/m^3$·hours) as an average for five years. The ozone levels at all the Danish rural measurements stations were below the target values both in 2018 and as an average for 2014 to 2018 (Ellermann et al., 2019).

Generally, ozone production over the Danish territory is low, and ozone is generally a long-range transport problem.

The Figure 3 shows that there in general is a decreasing trend in the maximum daily mean 8 hour ozone concentration in Denmark as a function of time (Ellermann et al., 2020). As can be seen, the ozone levels have decreased since the 1990s and been constant in later years. It is therefore not likely that a new derogation will have a negative influence on this trend. This conclusion is supported by the fact that ozone formation over Danish territory is very limited.

Moreover, according to research, ozone formation in Denmark is restricted by the concentration levels of nitrogen oxides in the air. Thus, reduction in the levels of hydrocarbons has hardly any effect on the amount of ozone created in Denmark.

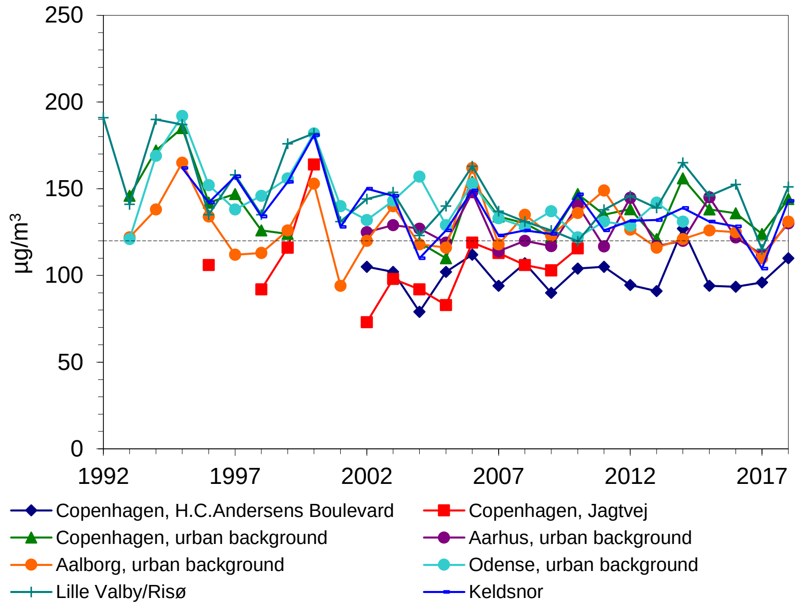

Figure 3. The maximum daily 8 hour average ozone concentration since 1990 (Ellermann et al., 2019). The dotted line shows the 120 µg/m³ concentration that must not be exceeded more than 25 times as an average for the latest three calendar years. The increases observed at the two street stations in Copenhagen since 2000 are due to decreases in the traffic related emissions of nitrogen oxides that chemically breaks down ozone.

4. Status of air quality of benzene in Denmark and the potential impact of the dispensation on benzene levels in Denmark

The EU air quality directive (2008/50/EC) includes a limit value for benzene in ambient air. This limit value entered into force in 2010 and specifies that the concentration of benzene must not exceed 5 µg/m³ as annual average for a calendar year.

Benzene concentrations are measured at one urban street station in Denmark (Jagtvej, Copenhagen). Figure 4 shows the long-term trend for benzene (Ellermann et al., 2020). The concentration has decreased with more than 90% during the last two decades and are well below the limit value and the benzene concentrations have decreased steadily during the period. It is therefore concluded that a continuation of the derogation for 70 kPa in summertime will not have a negative influence on the concentration of benzene.

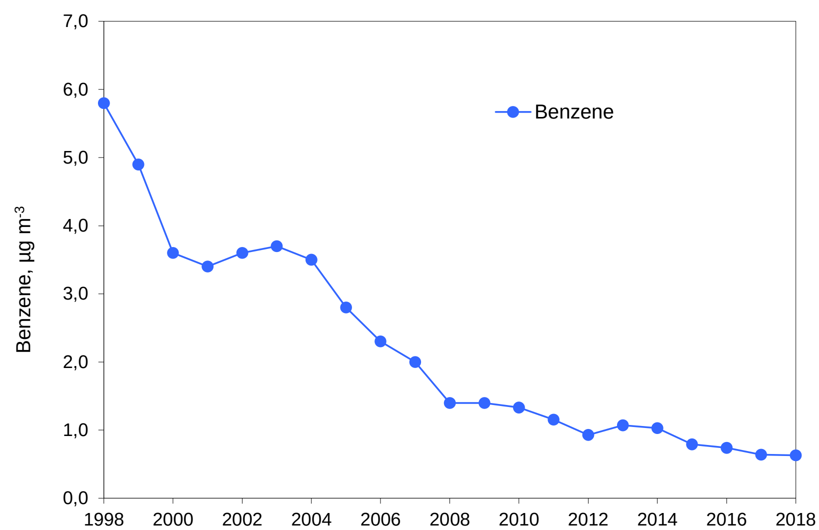

Figure 4. The long-term trend for benzene measured at the street station Jagtvej in Copenhagen (Ellermann et al., 2020).

5. Conclusions

5.1 Impacts on NMVOC emissions

The Danish obligations under Directive (EU) 2016/2284 (NECD) is a reduction of 35 % in 2020 compared to the emission level in 2005 and a reduction of 37 % in 2030 compared to the emission level in 2005. Table 3 below shows the 2005 and 2018 emission level from the latest submitted inventory as well as the latest reported projections (Nielsen et al., 2020). Data are shown excluding emissions from animal husbandry and manure management (NFR 3B) and agricultural soils (NFR 3D) as these sources are excluded from the reduction commitments in the NECD. The projections are made using the same methodology as the inventory, so the emissions are comparable and consistent over the time-series.

Table 3 Historic and projected NMVOC emissions for Denmark.

	2005	2018	2020	2030
NMVOC emissions, kt	106.6	64.6	61.7	58.8

It can be seen that the expected reductions in 2020 and 2030 are 42 % and 44 % respectively. A new projection is under preparation for reporting in 2021, the calculated adjustments based on the new projection is 42 % in 2020 and 46 % in 2030. The absolute difference in emissions between the ‘ceiling’ and the projected emission is 7.6 kt in 2020 and 10.1 kt in 2030.

As described in Chapter 2, the impact of the suggested change in vapour pressure is very small compared to the total NMVOC emissions and compared to the margin in the Danish projection to the fulfilment of the Danish reduction commitment. Even a conservative estimate only leads to an increase in emissions of less than 0.3 kt.

As such, a dispensation to change the vapour pressure will not affect Denmark’s ability to comply with the emission reduction commitments set out in the NECD.

5.2 Impacts on air quality

As described in Chapter 3 and 4, the concentrations of benzene and ozone are below the limit values in the past where the higher vapour pressure has been allowed in the summer months indicating that continuing this will not affect the adherence to concentration limit values.

6. References

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