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Potential reduction of traffic noise by the means of increased fleet of electric vehicles using a combination of low-noise tyres and low-noise road surfaces

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In the future, the number of zero-emission vehicles like electric and plug-in hybrid vehicles (in electric mode) is expected to be a substantial part of the vehicle fleet. In Norway, such vehicles already account for approximately 20 % of all new cars sold. Since these vehicles emit negligible noise related to the power-train, the tyre/road noise is the dominating noise source. In the LEO project, tyres designed for such cars have been tested on a wide range of road surfaces in Norway and Poland, including a poroelastic road surface. In addition, some noise tests have been made with electric cars fitted with special tyres and compared to normal cars. Depending on a combination of a tyre and a road surface, a reduction of tyre/road noise from 2 to 10 dB can be achieved. Calculations using the TRANECAM model, for six different scenarios have been performed for the potential reduction of the overall traffic noise levels in the future, with a percentage of electric/plug-in hybrid vehicles rising up to 25 % of the total vehicle fleet. Unexpectedly such a substantial change of fleet composition will have only a very limited influence of the noise level reduction – less than 0.5 dB. The best combination of low noise tyres and road surface (PERS) can reduce the L_{den}-levels by 6-7 dB in 2030.

1 Introduction

In the next 10 to 20 years, the zero-emission vehicles like pure electric vehicles (EV), plug-in hybrids (PHEV), hybrid electric vehicles (HEV) or hydrogen vehicles (HYV) will dominate the marked, especially vehicles in cities. Already about 25 % of new cars sold in Norway is either a pure EV or PHEV/HEV. Many of the "standard" HEVs, like the models from Lexus, Mercedes, Porsche, etc., can drive in electric mode only for a few kilometres and thus cannot be regarded as "zero-emission" vehicles. However, a recent investigation [1] has shown that the newer types of plug-in hybrids like the BMW i3 and i8 very rarely uses the combustion part of the engine. As long as the car is used for shorter distances or city driving, these cars are mainly using the electric mode, due to a driving range of around 130 km in this mode. For all these vehicles (in electric mode), the dominant source of external noise is the tyre/road noise.

2 The LEO project

The LEO project (***L**ow **E**mission **O**ptimized tyres and road surfaces for electric and hybrid vehicles, 2013-2016)* is a joint research project between the Technical University of Gdansk (TUG), Poland and SINTEF, Norway [2].

The main objective of this project has been to demonstrate the state-of-the-art of new passenger car tyres and road surfaces which has a potential to reduce road traffic noise as well as energy consumption for electric and hybrid vehicles (in electric mode), through a reduction of rolling resistance. Optimized combination of tyres and road surfaces for lower rolling resistance can also contribute to reduction of CO_2 for vehicles with normal combustion engines. In this paper, the focus is on the results relating the potential reduction of road traffic noise levels.

3 Measurement method

For most of the measurement program a CPX trailer has been used, mainly the CPX trailer of the Norwegian Public Roads Administration. To simulate the conditions of the type approval of the noise levels from tyres (UN ECE Reg.117), a modified CPX test method was used. In this modified method, additional weight was added to the trailer, to meet the requirements of 75 ± 5 % of maximum weight according to the load index of each tyre. The tyre pressure used (220-250 kPa) is somewhat higher than defined by Reg.117; but additional tests have shown that this do not influence the noise ranking of the tyres [3].

4 Tyres and roads used for measurements

In the LEO project, a wide range of combinations of road surfaces and passenger car tyres have been measured on road surfaces in Poland and in Norway [5]. Table 1 gives an overview of the tyres used by SINTEF.

Table 1: Tyres used by SINTEF, road measurements

Tyre Symbol	Manufacturer	Type	Size	No
CONVENTIONAL TYRES				
T1066	WANLI	S-1200	195/60R15 88H	4812
T1067	CONTINENTAL	Conti.EcoContact 5	195/60R15 88H	1213
T1071	VREDESTEIN	QUATRAC 3	195/60R15 88V M+S	3712
T1072	YOKOHAMA	W.drive	195/50R15 88T M+S	1812
T1079	BRIDGESTONE	ECOPIA EP001S	195/65R15 91H	4612
T1080	MICHELIN	ENERGY SAVER X GREEN	215/55R17 94H	1712
T1081	DUNLOP	SPORT BLURESPONSE	195/65R15 91H	2413
T1082	MICHELIN	ENERGY SAVER + Extra Load X GREEN	195/65R15 95T	313
T1093	NOKIAN	HAKKA GREEN	195/65R15 95T	1214
TYRES FOR ELECTRIC VEHICLES				
T1083	MICHELIN	ENERGY EV GREEN	195/55R16 91Q	1212
T1095	DUNLOP	ENASAVE 2030	175/55R15 77V	3911

These tyres have also been tested by TUG, either in their laboratory on drum facilities [8] or during road measurements using their single tyre CPX trailer Tiresonic Mk4. The tests performed by TUG included also reference tyres [4], like the SRTT tyre and Avon AV4, as well as two additional tyres designed for EVs:

- Conti.eContact BLUECO@, 195/55 R18 90T (also tested later in dimension of 205/55 R16)
- Bridgestone ECOPIA EP500, 155/70R19 84Q

The tyres were tested on seven dense SMA surfaces in Norway, with maximum chipping size from 8 to 16 mm. In Poland, the tyres were tested on five dense surfaces (SMA8 and SMA11), one double layer porous surface (DPAC8/16) and one poroelastic surface (PERS-PL1) which was laid as a part of the PERSUADE project [6].

5 Measurement results

Figures 1 to 4 show the results from measurements done by SINTEF using the CPX trailer at 50 km/h on a new smooth surface (SMA11 – not exposed to studded tyres in Norway), on a rough surface, SMA16, and on two low noise surfaces in Poland, DPAC and PERS-PL1. In the figures, the EV tyres are marked in blue, while the conventional tyres are marked in red. The average level for all tyres are in black. All results are temperature corrected to 20 ºC [5].

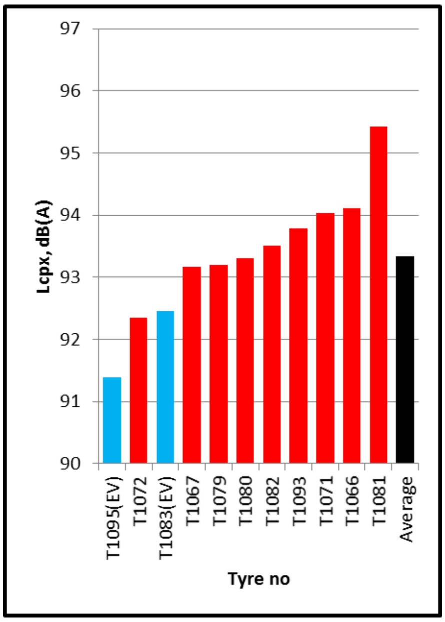

Figure 1: L_{cpx} on SMA11 surface

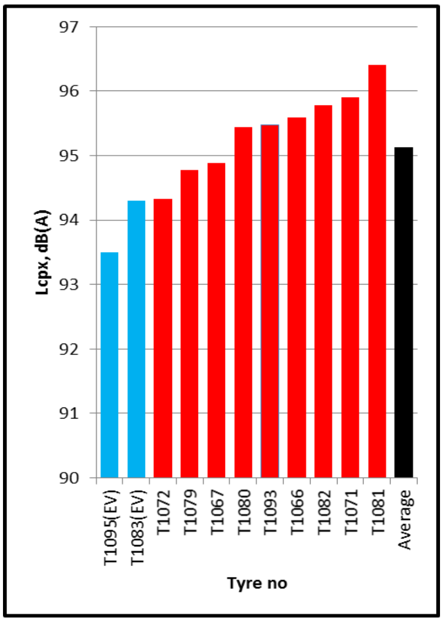

Figure 2: L_{cpx} on SMA16 surface

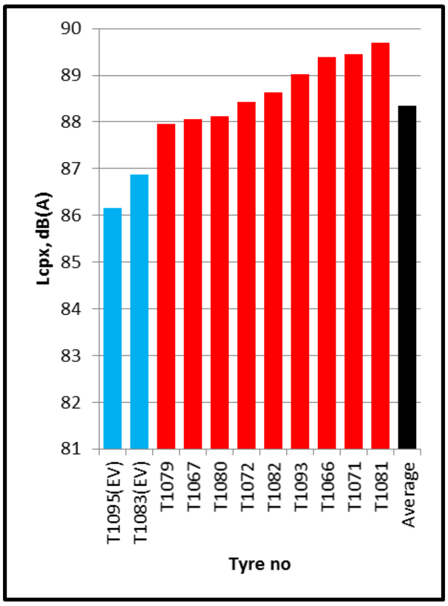

Figure 3: L_{cpx} on DPAC surface

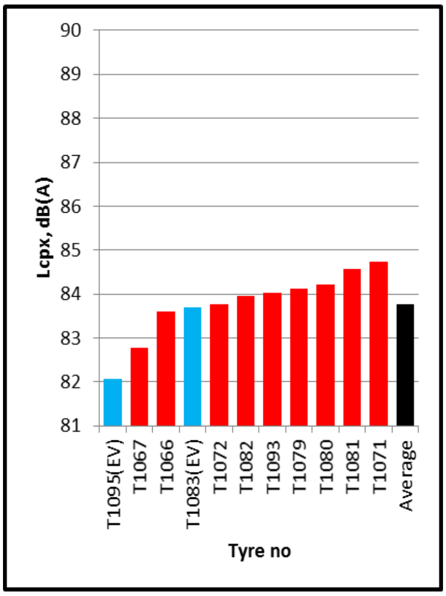

Figure 4: L_{cpx} on PERS-P1 surface

On most of the surfaces tested, the tyres for EVs were the quietest or among the quietest tyres.

Compared to the results obtained on the rough SMA16 surface (in Norway), on the average the noise reduction was found to be about 5 dB when tested on SMA8 surface, 7 dB on DPAC and 11 dB on PERS.

6 Reduction of traffic noise levels

The results of the measurements in Norway and Poland show that an EVs or PHEVs driven in electric mode when combined with quiet tyres and a low noise surface, can reduce the overall road traffic noise. Especially, since they do not have any significant noise contribution of the powertrain noise, as for vehicles with conventional combustion engines. The potential reduction will depend on several parameters:

- choice of tyre,

- choice or reference surface,
- choice of low noise road surface,
- the number of EV/PHEV with low noise tyres in a traffic flow.

Some theoretical calculations have been made in order to predict the potential reduction on the overall road traffic noise levels (L_{den}).

6.1 Methods used and scenarios

Heinz Steven has developed the noise calculation method, TRANECAM, for the Federal Ministry of Transport, Building and Urban Affairs in Germany. The benefit of this model is that it is possible to calculate future potential noise reduction as a function of different noise mitigation measures, such as the effect of more stringent noise limits, as approved by EU, effective from July this year [7].

Based on the measurement results from the LEO project, Steven has calculated the potential reduction of L_{den} for different scenarios.

The model needs some important input parameters, such as:
- type of road
- traffic mix
- vehicle speeds
- vehicle fleet composition

Since there may be a difference on the vehicle fleet composition (age, vehicle types) for different countries, the calculations have been made for two categories:
- standard EU vehicle fleet composition (default values in TRANECAM), assumed representative for Poland,
- present Norwegian vehicle fleet composition with approximately 2 % of EVs/PHEVs.

Among the available road categories and vehicle speed limits, the following categories have been chosen; see table 2:

Table 2: Road categories, speed limits and traffic mix

No	Road category	Speed limits, km/h Norway/Poland	ADT	% HDV
1	Motorway	100/120	40000	23
2	Rural Trunk Road	80/90	15000	12
3	Urban City Trunk	50	40000	9.5
4	Urban Access Residential	30	1000	4.3

For these 4 road categories, the following scenarios have been calculated, using a standard DAC 0/11 road surface as a reference (see table 3. The noise reduction is assumed to be a reduction of the tyre/road noise.

The noise level of the EVs (for tyre/road noise, L_{roll}) has been divided into 3 noise classes with different weighting factors:

- small: reference L_{roll} - 75%
- medium: L_{roll}+0,5 dB - 15%
- large: L_{roll}+1 dB - 10%

Table 3: Scenarios for calculations.

No	Scenario	Noise reduction, dB
1	Reference road surface, with average tyres	0
2	Reference road surface, replacement with best EV tyres	-2
3	Replacement with SMA8 and best EV tyres	-4
4	Replacement with DPAC and average of EV tyres	-6
5	Replacement with DPAC and best of EV tyres	-8
6	Replacement with PERS and best of EV tyres	-10

For each of the scenarios calculations have been made with a percentage of EVs/PHEVs varying from 0 % (2 % in Norway), 3, 5, 10, and 25 % of the total fleet composition. It should be mentioned, that due to both economic and user incentives for EVs (and to some degree also PHEVs) in Norway, already about 20-30 % of the vehicle fleet in the biggest cities in Norway are already EVs/PHEVs. All calculations are A-weighed L_{den} - values based on the traffic mix shown in table 2.

The TRANECAM model enables a prediction of future effects of the different scenarios given in table 3, in addition to the effect of the new EU directive EU/540/2014. This directive, corresponding to ECE Reg.51-03, defines a new type approval test method as well as new noise limits for vehicles, effective from July 2016. In the LEO project, calculations have been made for the years 2016, 2020, 2025 and 2030.

6.2 Calculation results

All results shown here are for the vehicle fleet composition for Norway. The results calculated for the EU/Poland vehicle composition are almost identical – they are within a 0.1 dB(A) difference.

Table 4 shows the results for the reference situation in Norway (2 % EVs), for all the 4 road categories (table 2). The reduction in this table is only due to the effect of the EU directive. The prediction is based on the adopted limits for Phase 1 and Phase 2 [7].

Table 4: Reduction of L_{den} [dB(A)] for reference situation

Year	Road category			
	1	2	3	4
2016	0	0	0	0
2020	0.3	0.3	0.3	0.3
2025	1,0	1.0	0.9	0.9
2030	2.2	2.3	1.5	1.5

The results of the different scenarios for road categories 3 and 4 (table 2) are shown in figures 5 and 6. The calculations are for the year 2016.

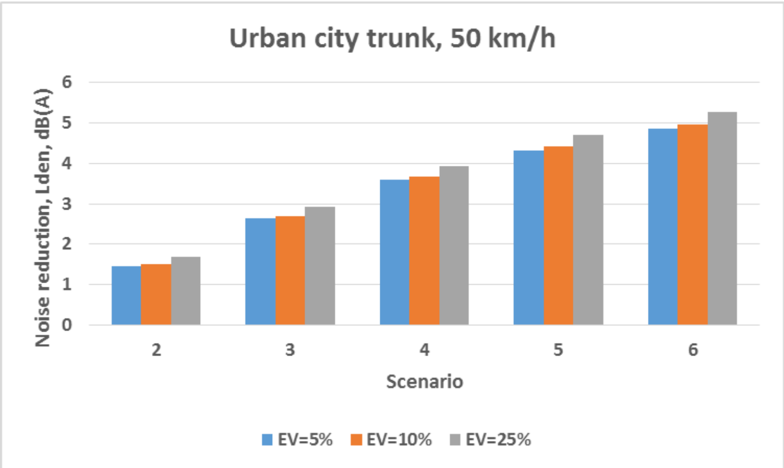

Figure 5: Noise reduction of L_{den} for different scenarios and different % EVs in the traffic mix. Road category: Urban city trunk, 50 km/h

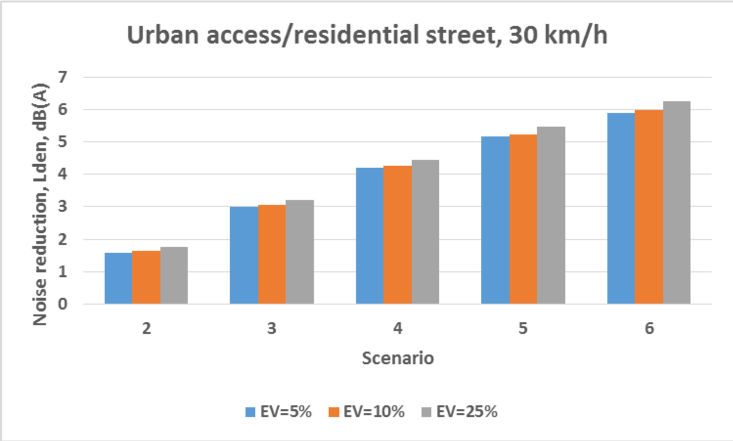

Figure 6: Noise reduction of L_{den} for different scenarios and different % EVs in the traffic mix. Road category: Urban access/residential, 30 km/h

When changing to more silent tyres only, like the most silent EV tyres (scenario 2), one can obtain a moderate (about 1.5 dB) reduction of L_{den}-levels. By combining more silent tyres and low noise road surface, the reduction can be 3-6 dB at 30 km/h and 2.5-5 dB at 50 km/h, depending on the choice of a road surface. The increase of EVs in the traffic composition from 3 to 25 % have a very limited influence of the noise level (a reduction less than 0.5 dB). For the road categories 1 and 2 (table 2), the noise reduction results are similar to the results given in figures 1 and 2 (calculated only with a share of EVs of 3 %, as the increase of EVs in the traffic is mainly expected for city traffic).

Figures 7 and 8 show the results of performed calculations to the year of 2030 for scenarios 2 and 3. By keeping the reference road surface (DAC 0/11) and introducing tyres which reduce the tyre/road noise by 2 dB (scenario 2), the expected noise reduction of L_{den} in 2030 is about 3 dB (figure 7). If such tyres are introduced together with a smooth SMA8 surface achieving an extra 2 dB reduction of the tyre/road noise (4 dB in total), then the expected noise reduction in 2030 is calculated to be about 4.5 dB (figure 8).

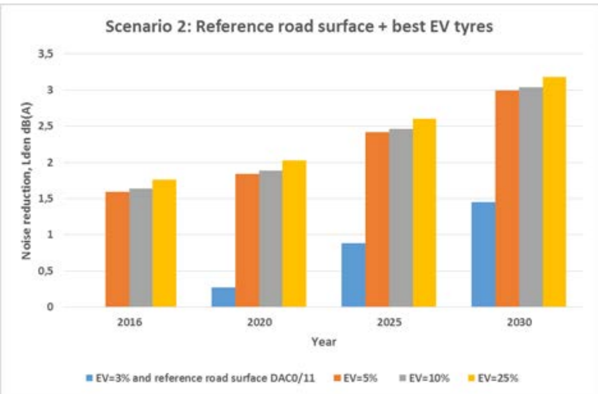

Figure 7: 2016-2030: Noise reduction of L_{den} for scenario 2.

Road category: Urban access/residential, 30 km/h

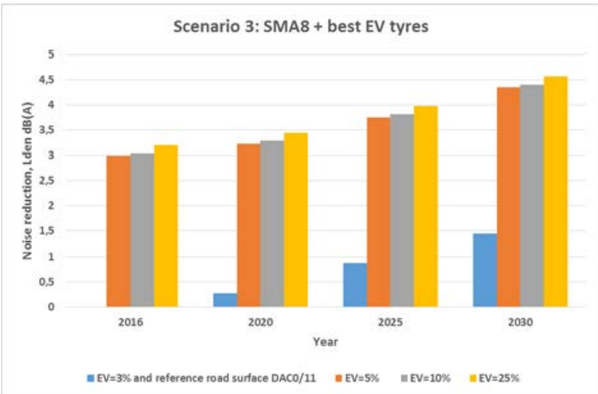

Figure 8: 2016-2030: Noise reduction of L_{den} for scenario 3.

Road category: Urban access/residential, 30 km/h

Figures 9 and 10 show the expected noise reduction when a double layer porous surface is combined with the average EV tyres (scenario 4) or with the best EV tyres (scenario 5). Figure 11 show the possible reduction when a poroelastic road surface is combined with the best EV tyres (scenario 6). These combinations show an additional potential noise reduction of 2-3 dB, compared to scenarios 2 and 3.

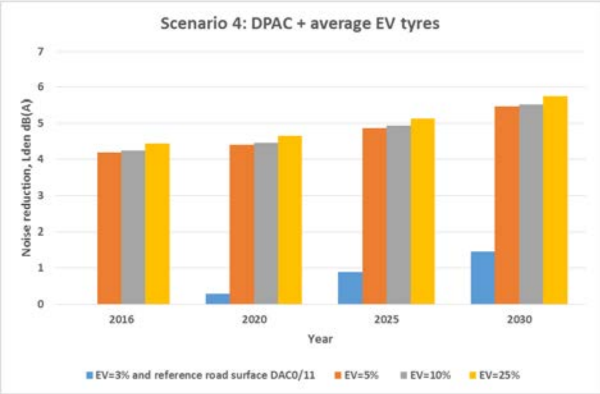

Figure 9: 2016-2030: Noise reduction of L_{den} for scenario 4.

Road category: Urban access/residential, 30 km/h

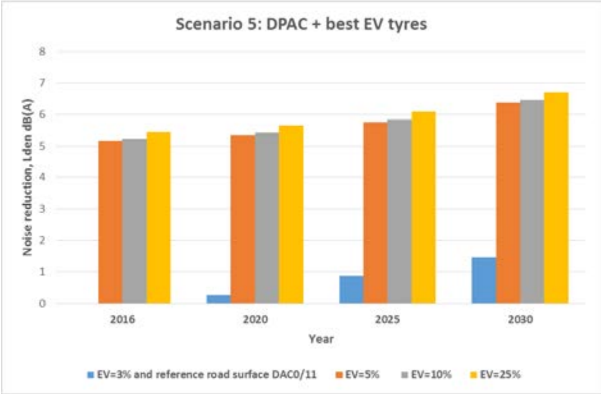

Figure 10: 2016-2030: Noise reduction of L_{den} for scenario 5.

Road category: Urban access/residential, 30 km/h

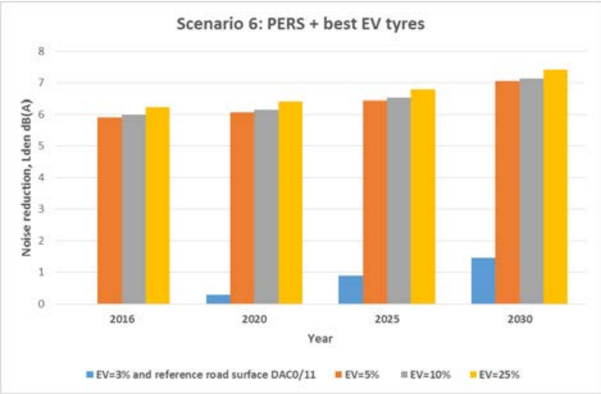

Figure 11: 2016-2030: Noise reduction of L_{den} for scenario 6.

Road category: Urban access/residential, 30 km/h

7 Conclusions

The following conclusions can be made:

- On most of the road surfaces tested, the tyres dedicated for EVs were the quietest or among the quietest tyres. However, on the drum facilities of TUG, such ranking was not found [8].
- Compared to a rough SMA16 surface, the best EV tyres gave a reduction of tyre/road noise level (CPX) of 5 dB by changing to a low noise SMA8 surface and 11 dB on a PERS surface.
- A "do nothing" scenario (only rely on the effect of EU/ECE regulations) will only give a small reduction of L_{den}-levels of about 1.5 dB in 2030.
- By a combination of low noise (EV) tyres and low noise road surfaces, a reduction of L_{den}-levels of 4-7 dB, depending on the choice of road surface, can be obtained.
- An increase in the share of EVs in the total mix of traffic up to 25 % have only a minor effect on the L_{den}-levels (less than 0.5 dB).

Acknowledgements

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