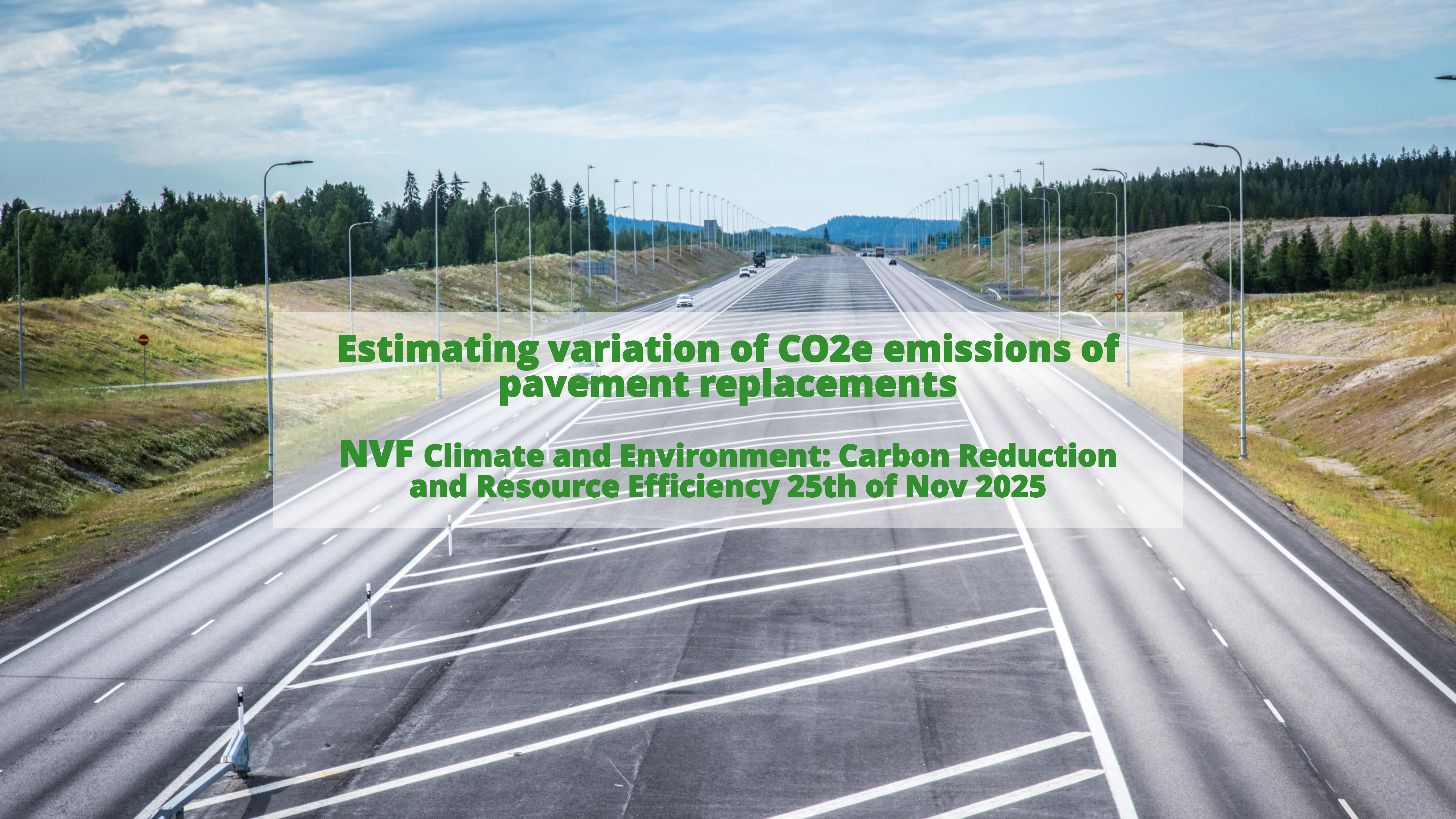

Estimating variation of CO2e emissions of pavement replacements

NVF Climate and Environment: Carbon Reduction and Resource Efficiency 25th of Nov 2025

Objective of the study

- The purpose of the study is to provide information and guidance on how pavement replacements should be considered in the LCA-assessment.
- The study considers the impact of pavement deterioration on the climate emissions of pavement replacements (B4-phase)
- The study covers only the main roads where wearing caused by studded tires is the main cause of pavement deterioration.
- On low volume roads pavement replacements cannot be estimated with the same model because the reasons for pavement replacements are different – like deteriorations caused by low bearing capacity of road structures and subgrade.
- 50-year service period is considered in the assessment.

A1-A3 **Production stage**	**A4-A5** **Construction**	**B** **Operating phase**		**C** **Demolition phase**
A1 Raw material supply	A4 Transport to site	B1 Use	B5 Refurbishment	C1 Deconstruction
A2 Transport	A5 Site operations	B2 Maintenance	B6 Energy use	C2 Transportation
A3 Manufacturing		B3 Repair	B7 Water use	C3 Waste processing
		B4 Replacements		C4 Disposal
D Additional Benefits and disadvantages beyond the life cycle				

The CO2 emissions of road construction are assessed according to the FTIA guideline VO 42/2023 Low Carbon Assessment Method for Infrastructure Construction. The assessment covers the product phase (A1-A3), the construction phase (A4-A5) and the replacements (B4). The service life is 50 years.

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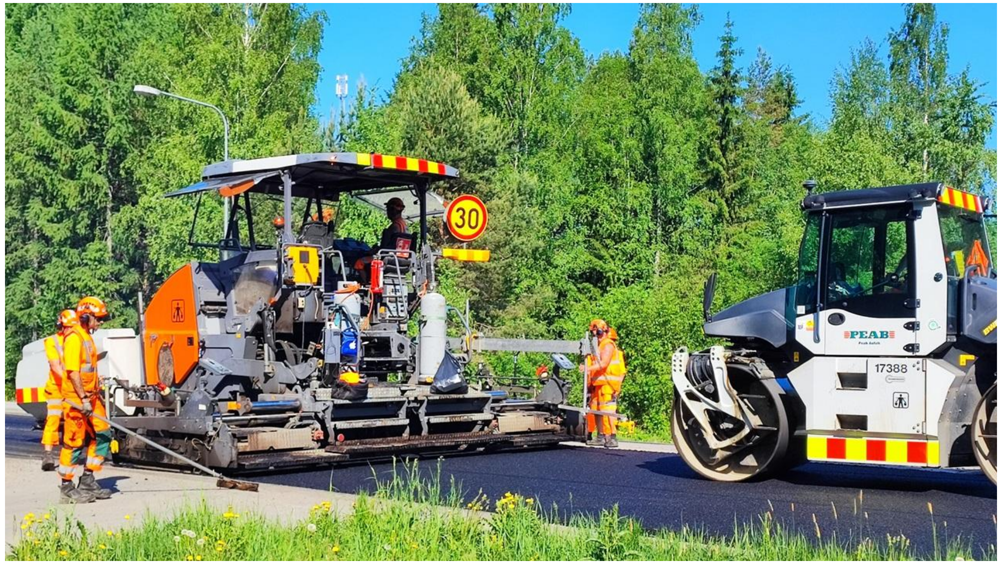
Considered paving methods

Pavement milling and repaving, HMA



Pavement hot in place recycling, HIR

Hot in place recycling –method (REM or Remix) is a resurfacing method where the old asphalt pavement (asphalt concrete (AB) or stone mastic asphalt (SMA)) is heated on the road with propane heaters, milled off, mixed with the new asphalt mass, re-applied and compacted.

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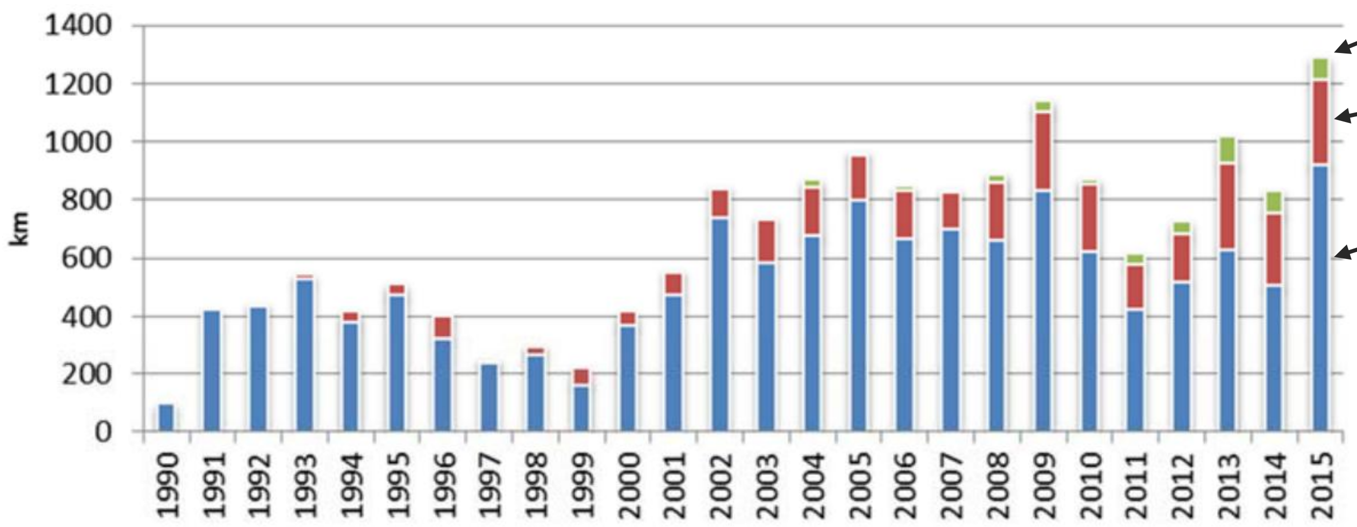
Hot in place recycling –method



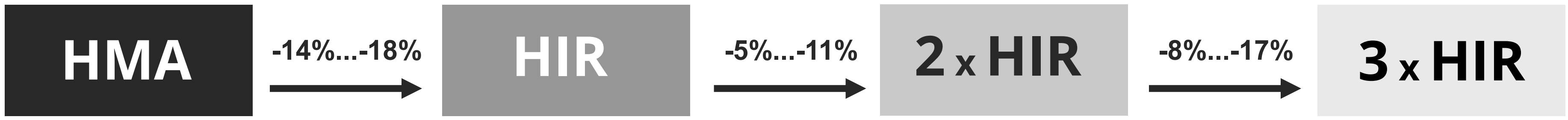
Two previous layers HIR, then HMA

Previous layer HIR, then HMA

Previous layer HMA

https://www.doria.fi/bitstream/handle/10024/159033/lts_2018-39_978-952-317-584-6.pdf?sequence=1&isAllowed=y

- Hot in place recycling has been used in Finland since 1990's, the method was developed to repair pavement ruts caused by studded tires
- HIR can be used several successive times, pavement service life after HIR is shorter than service life of corresponding HMA



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Inputs of emission calculations

Asfalt milling and repaving, MIL+HMA

- Emissions from pavement production (A1-A5)
  - Emissions from materials (A1-A3)
    - Raw material production (A1)
    - Raw material transportation to the factory (A2)
    - Asphalt mass production (A3)
  - Emissions from transportation (A4)
    - Transportation to the work site
    - Transportation of milling debris
  - Paving emissions A5
    - Milling emissions
    - Spreading emissions
    - Compacting emissions

Pavement hot in place recycling, HIR

- Emissions from pavement production (A1-A5)
  - Emissions from materials (A1-A3)
    - Raw material production (A1)
    - Raw material transportation to the factory (A2)
    - Asphalt mass production (A3)
  - Emissions from transportation (A4)
    - Transportation to the work site
  - Paving emissions A5
    - Pre-heating emissions
    - Milling and remixing emissions
    - Compacting emissions

The study used following assumptions:

Emissions of the production of HIR-pavement (A1-A5) =

0,8 – 1,2 * emissions of HMA pavement

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The deteoriation model of pavements

- The timing of successive paving operations is estimated using pavement deterioration model (formulas 1 and 2)
- The limit value for the rut depth was selected according to the FTIA's paving policy's condition classes 1 and 2
- Several general strategies for phase B4 paving works were considered:
  - 0 x HIR: only MIL+HMA –method is used
  - 1 x HIR: cycle HIR - MIL+HMA is repeated
  - 2 x HIR : cycle HIR - HIR - MIL+HMA is repeated
  - 3 x HIR : cycle HIR - HIR - HIR - MIL+HMA is repeated
- Patches and paving methods that only refurbish part of the lane were not been included in the analysis

$$RUT\ DEPTH = 1{,}2 \times \left[A + t \times 0{,}3\, {}^{mm}/_{y} \times \frac{2 \times ADT_{LANE}}{1000\, {}^{veh}/_{day}} \times k_W \times k_S \times \frac{KN}{46} \right]$$

A	*post-compaction of the pavement*
t	*pavement service life*
ADT_{LANE}	*average daily traffic per lane (veh/day)*
k_w	*lanewidth coefficient*
k_s	*winter speed limit coefficient*
KN	*pavement wear coefficient*

$$KN = TP \cdot MP \cdot (9{,}4 + 2{,}21 \cdot KM)$$

TP	*paving method coefficient*
MT	*mass type coefficient*
KN	*abrasion resistance of the aggregate used in the asphalt mass (according to the Asfalttinormit)*

Paving method coefficient TP for different paving methods
(due to the shorter service life of HIR pavements)

HMA: 1
1 x HIR: 1,15
2 x HIR: 1,25
3 x HIR: 1,5

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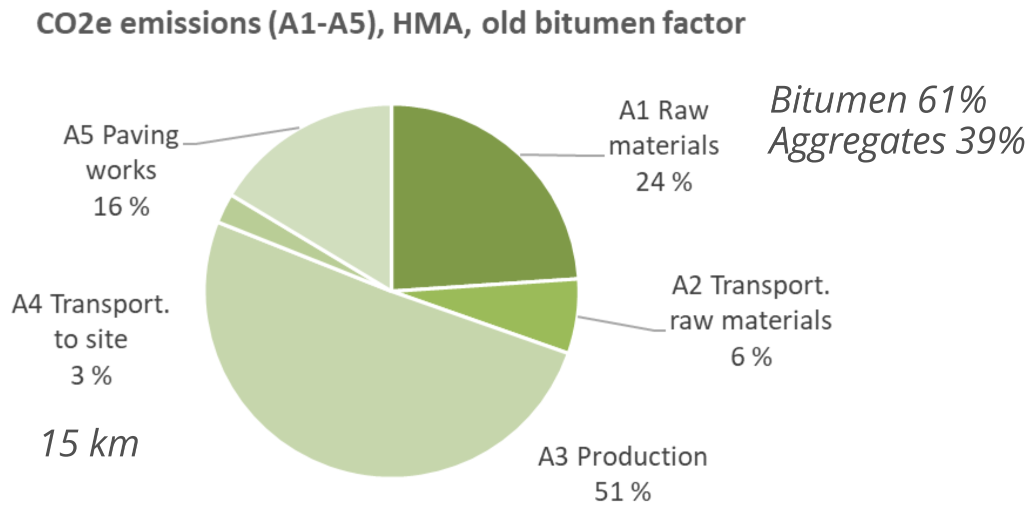
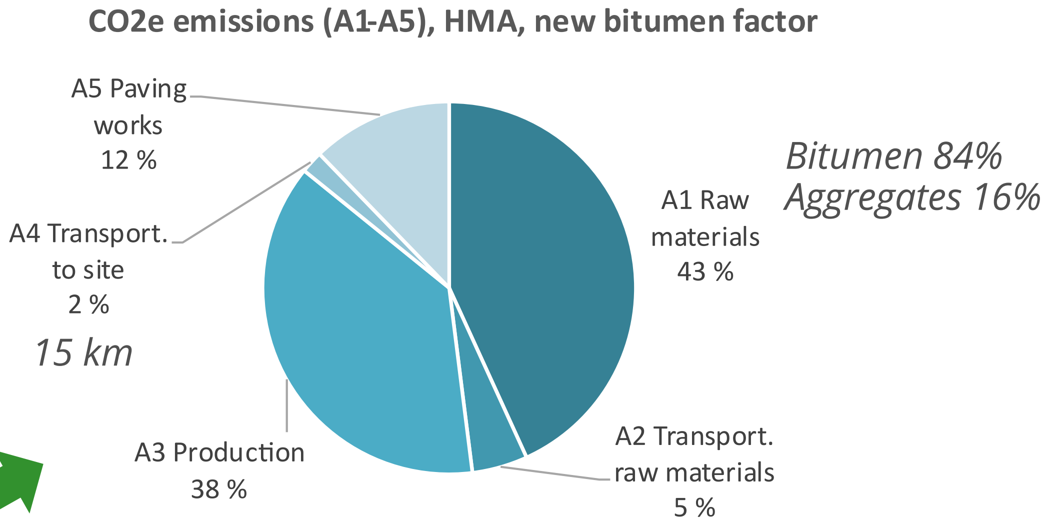
Variables used in the calculation

- Bitumen emission factor 159 kg CO2e/t (current Finnish factor) or 530 kg CO2e/t (Eurobitumen 2025 factor)
- Paving costs based on the FTIA data of actual costs per m2.
- HIR additional mass share 30%
- Paving over the entire lane width approximately every 25 years

- Speed limit 80 km/h or 100 km/h
- Asphalt types AB16, AB22, SMA16 and SMA22
- Transportation distance 84 km, 15 km and 50 km.
- 1-lane: ADT 4 000 – 20 000 veh/day, cross-section 10/7, lane width 3,5 m, processing width in operations 8 m
- 2-lane; ADT 10 000 – 50 000 veh/day, Width of the roadway pavement 11,75 m, lane width 3,75 m, shoulders 1,25 m and 3,00 m, processing width in operations on the roadway 8,5 m





Half of the emissions from the production of HMA pavement mass (A1-A3) from raw materials, when the emission factor of bitumen is in accordance with Eurobitume 2025.

Two-fifths of the emissions from pavement production (A1-A5) from raw materials (transport distance 15 km).

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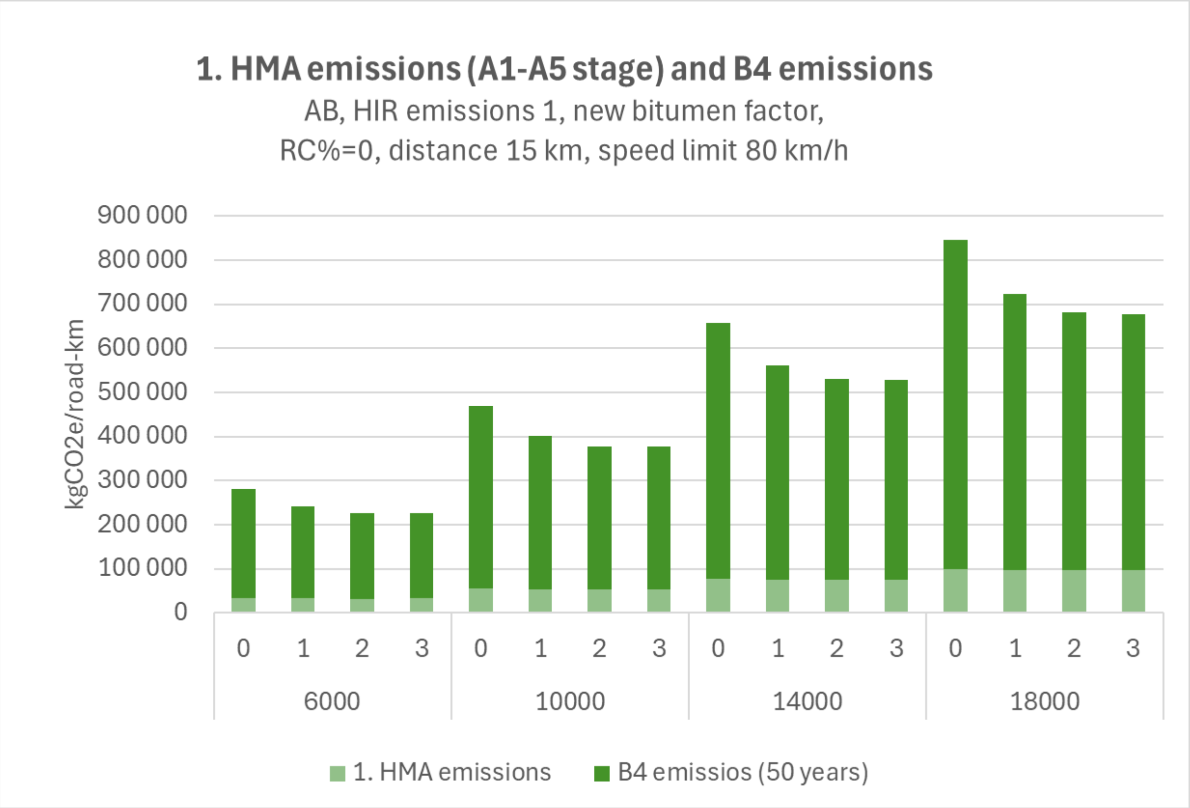
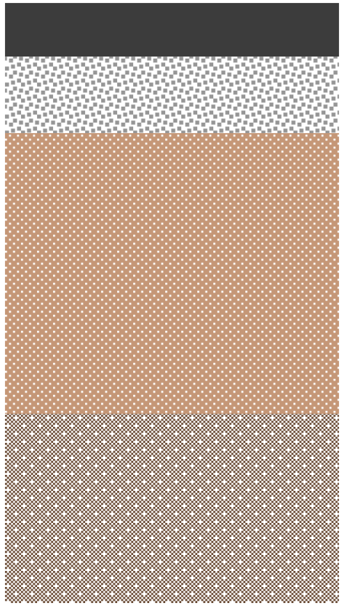
Preliminary results for single-carriageway roads, 50-year maintenance period





- CO2e emissions from the production of investment pavement (last 4 mm layer is considered) are 10-30% of the emissions over the entire 50-year life cycle.

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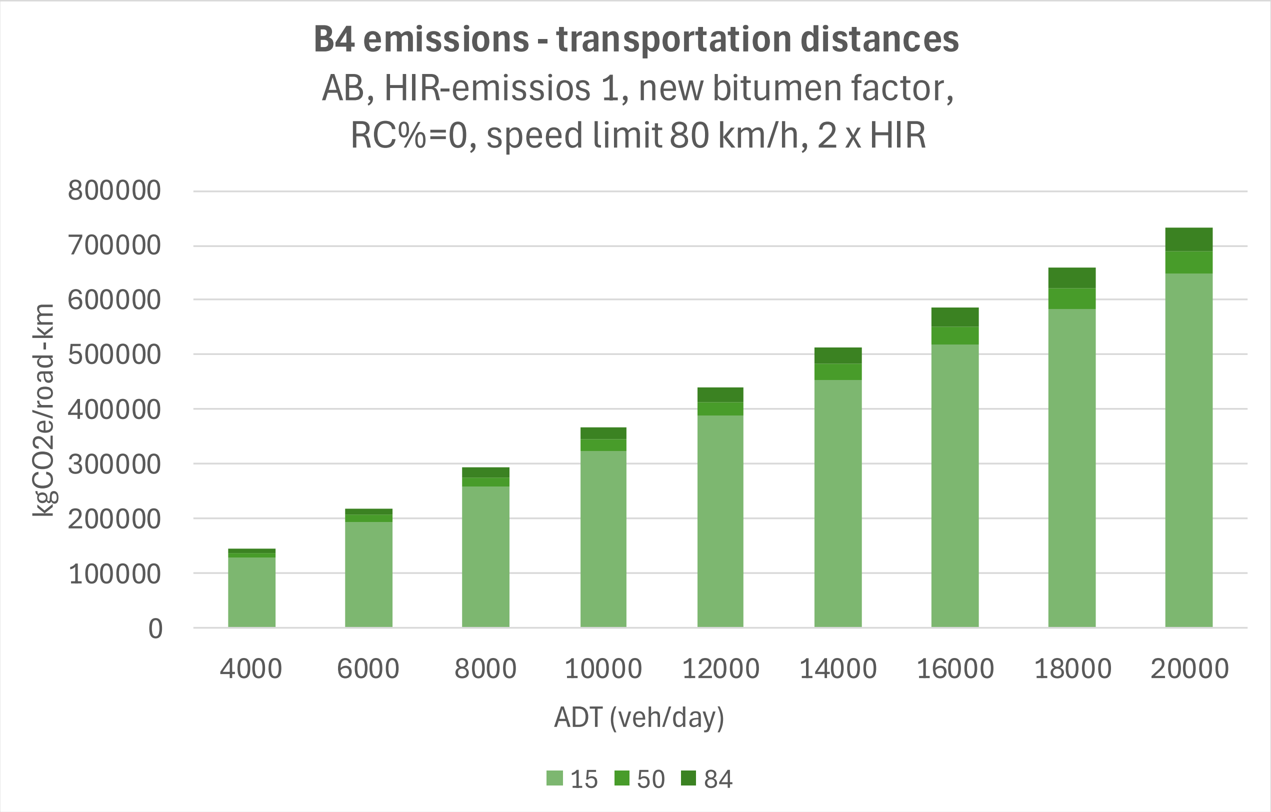
Preliminary results for single-carriageway roads, 50-year maintenance period



- Doubling transport distances increases B4 CO_2e emissions of asphalt pavements by 3-6%.

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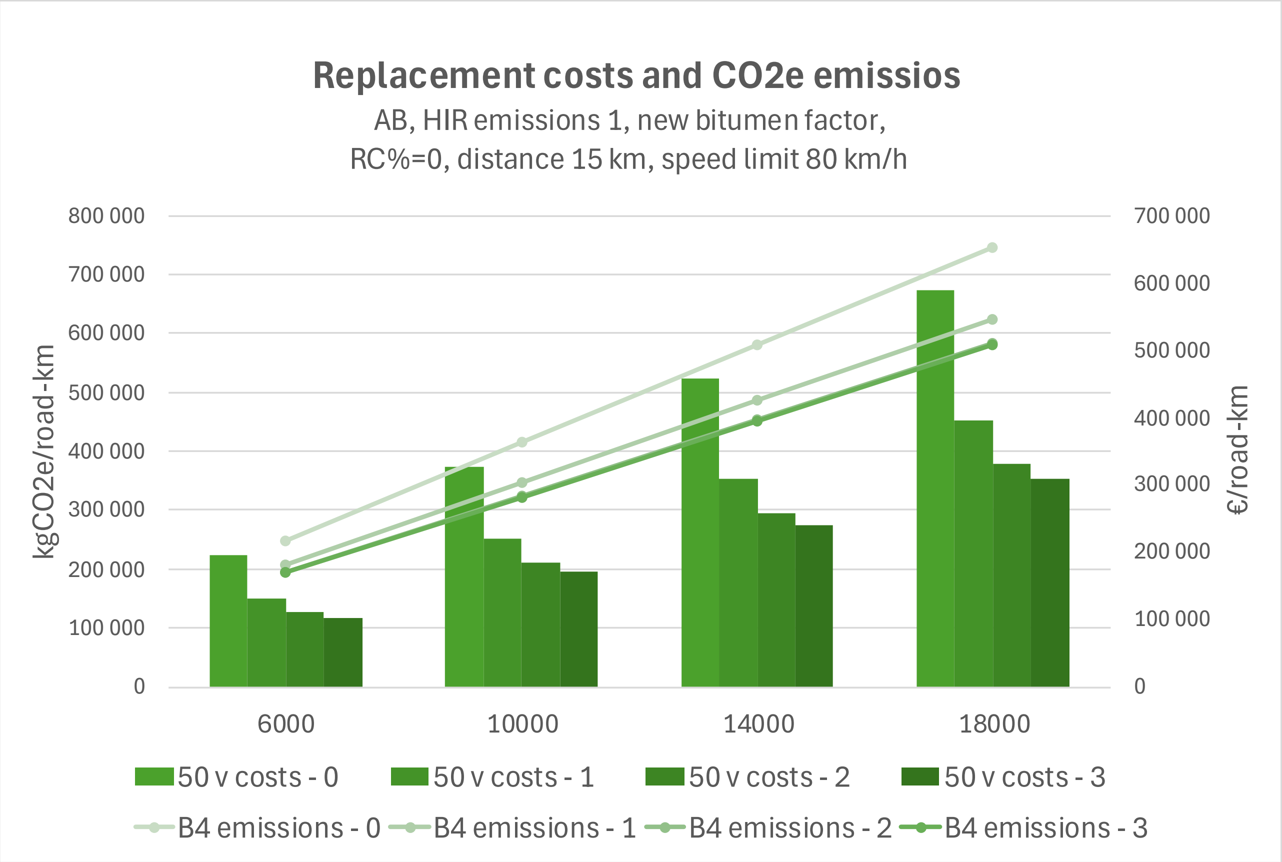
Preliminary results for single-carriageway roads, 50-year maintenance period



- Using hot in place recycling significantly reduces both climate emissions and maintenance costs over a 50-year maintenance period
- There is no significant difference in emissions and costs between the 2xHIR and 3xHIR maintenance strategies

- Next:
  - Presented study will be reported as a publication by the Finnish Infrastructure Agency
  - The actual chains of paving works, actual service life and replacement intervals will be studied based on FTIA historical data

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