

Sustainability and road transport in Norway

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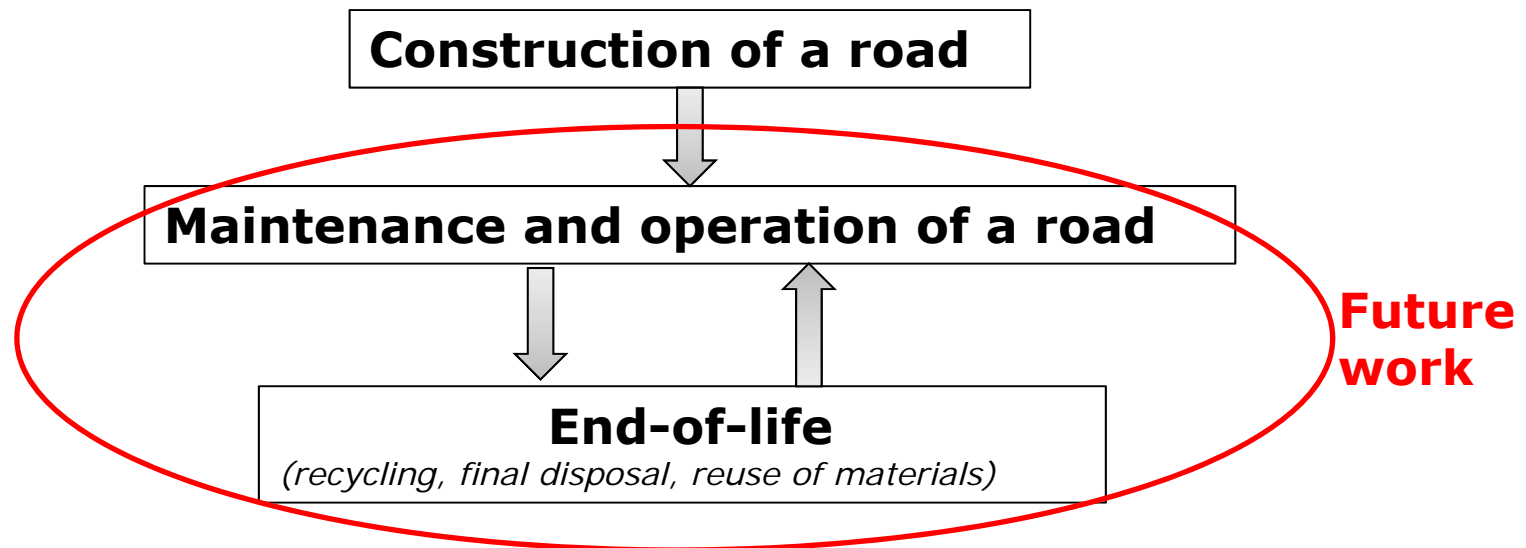


Content

- LCA for road construction and coefficients
- Motorway construction E 18 Sky-Langangen
- Motorway construction E6 Labbdalen – Skaberud
- CO_{2eq.} carbon footprint for old and new road
- Conclusion

LCA for road construction

- The goal is to include all possible direct and indirect energy use and its consequently impact on greenhouse-gas emissions (mainly CO₂) during road construction
- Life-Cycle assessment of road infrastructure construction is based on these phases:





Energy usage and CO₂ emissions

$$\Sigma Q = \mathbf{m} * \mathbf{k}_Q \quad [\text{kWh}], [\text{MJ}]$$

$$\Sigma \text{CO}_{2\text{eq.}} = \mathbf{m} * \mathbf{k}_{\text{CO}_2} \quad [\text{kg}]$$

Where

m [kg]: Mass of materials

k_Q [kWh/kg], [MJ/kg]: Conversion coefficient, energy per kg material

k_{CO₂eq.} [kgCO₂eq./kg]: Conversion coefficient, CO₂eq. per kg material

Construction materials and k_{CO_2} and k_Q coefficient

Unit	k_{CO_2} coefficient		Unit	k_Q coefficient
[kg CO _{2eq.} *kg ⁻¹]	0.052	Asphalt	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	0.43 1.53
[kg CO _{2eq.} *kg ⁻¹]	0.081	Concrete	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	0.16 0.58
[kg CO _{2eq.} *kg ⁻¹]	0.0036	Crushed material	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	0.0072 0.026
[kg CO _{2eq.} *kg ⁻¹]	0.21	Explosive material	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	1.11 3.99
[kg CO _{2eq.} *kg ⁻¹]	0.34	Steel reinforcement	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	0.75 2.7
[kg CO _{2eq.} *kg ⁻¹]	1.1	Steel railings	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	6.8 24.5
[kg CO _{2eq.} *kg ⁻¹]	6.5	Stainless steel	[kWh*kg ⁻¹] [MJ*kg ⁻¹]	15.75 56.7
[kg CO _{2eq.} *liter ⁻¹]	2.9	Diesel oil	[kWh*l ⁻¹] [MJ*l ⁻¹]	11 39.6
[kg CO _{2eq.} *kWh ⁻¹]	0.205	Electricity from power station	[kWh] [MJ]	0.205 0.738

Main references:

- EPD (Environmental Product Declaration - The Norwegian EPD Foundation) – for electricity calculation
- VOLVO (Environmental Declaration) - calculation of machine production and machine wear
- ICE (Inventory of Carbon and Energy, version 2, University of Bath)



Motorway construction E18 Sky-Langangen 2009-2012

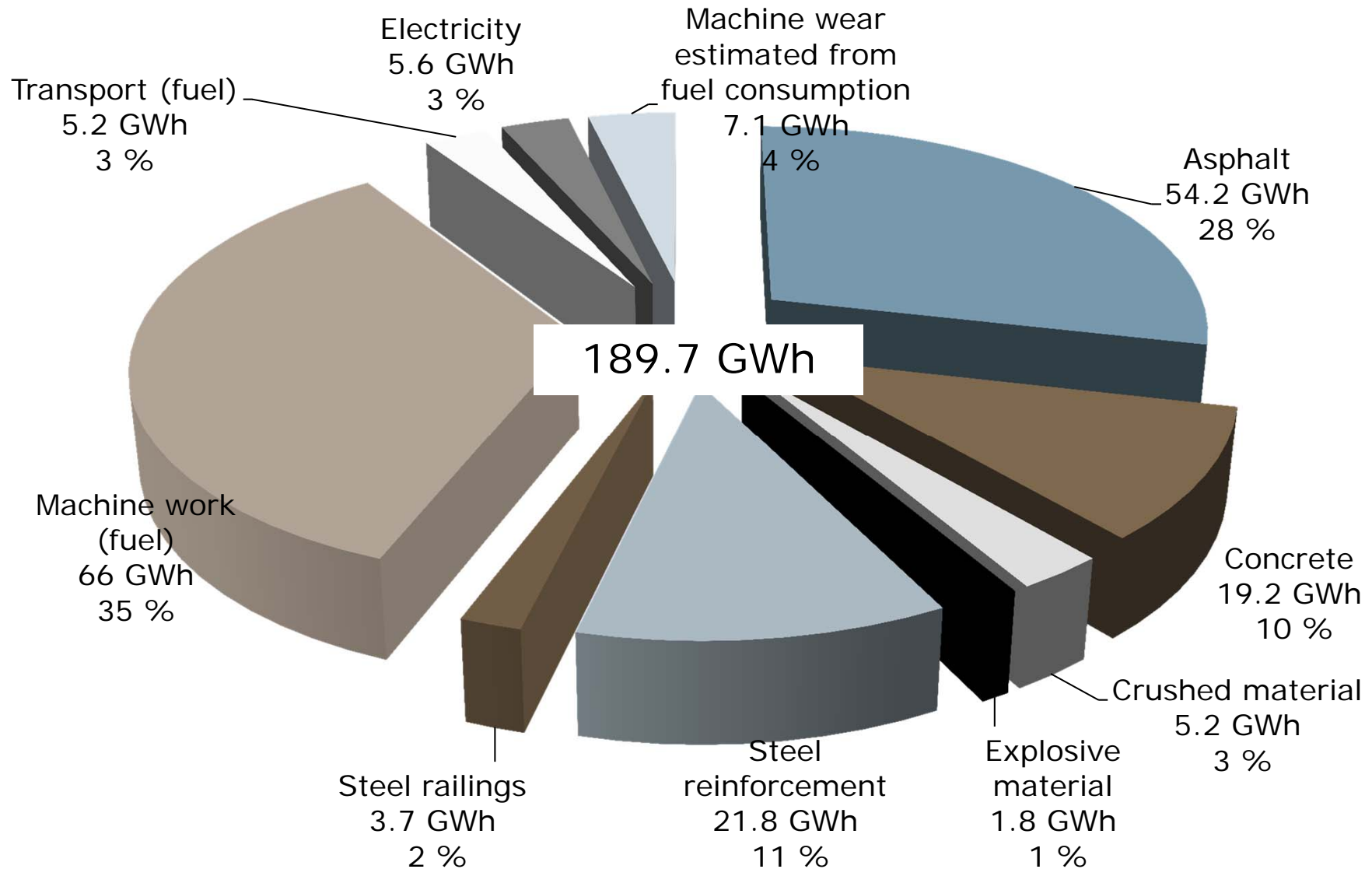
- Contractor: Veidekke ASA.
- The project “Energy use and greenhouse gas emission during construction, operation and maintenance of new road infrastructure” was carried out by Norwegian Public Roads Administration, Region South, in cooperation with University of Agder, Grimstad.



	Length [m]	The number of fields	Width [m]	Construction cost [10 ⁶ EUR]
E 18 Sky - Langangen	10 800	4	23	209

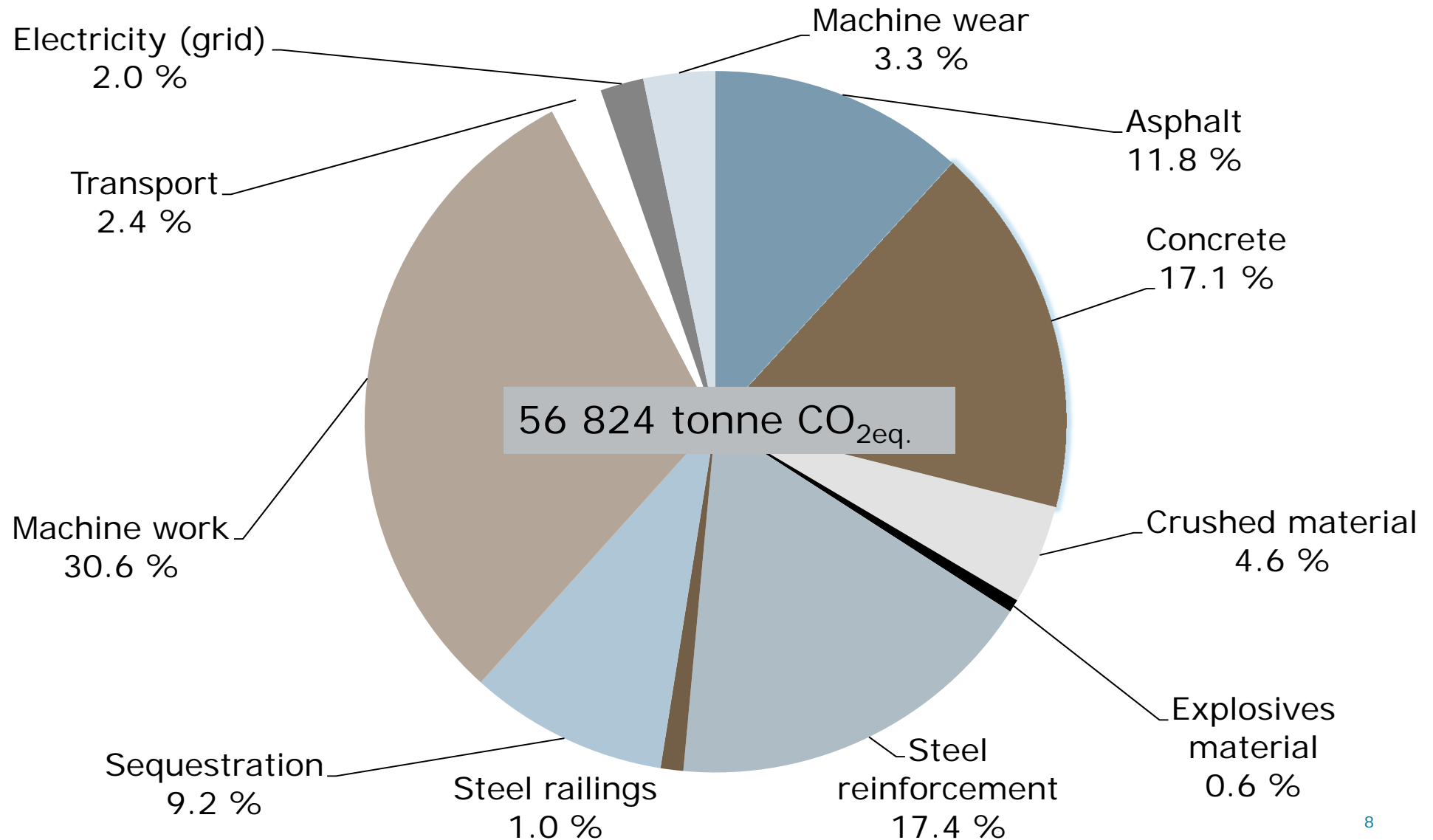
Motorway E18 Sky-Langangen

Energy use for construction activities and materials



Motorway E18 Sky-Langangen

CO_{2eq.} emission for construction activities and materials



Motorway construction E6 Labbdalen-Skaberud 2011-2012



Contractor: Skanska Norge AS

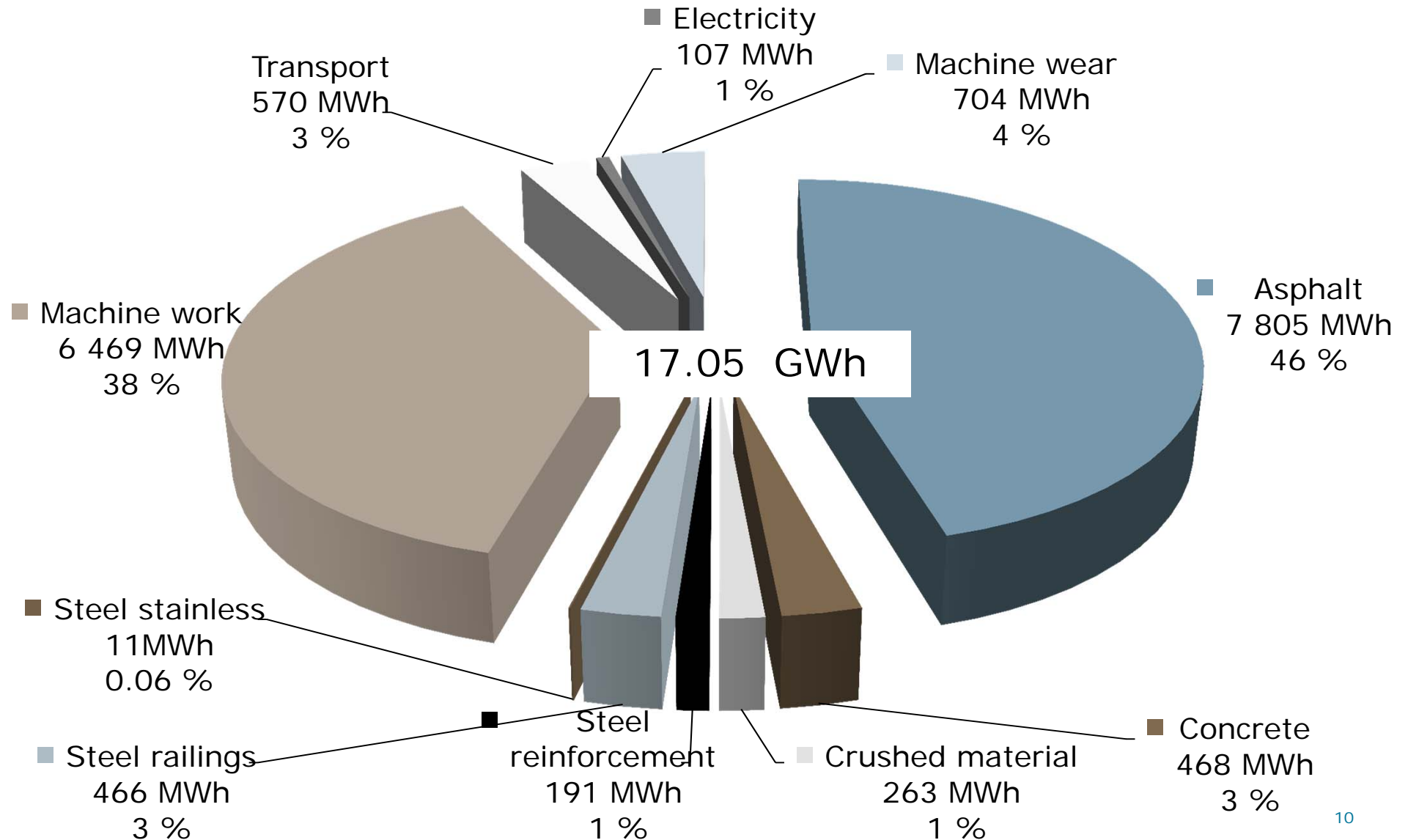


	Length [m]	The number of fields	Width [m]	Construction cost [10 ⁶ EUR]
E 6 Labbdalen – Skaberud (equivalent length 1355 m)	1100 470	4 2	21 10.5	16

Exchange rate: 8.00 NOK per EUR

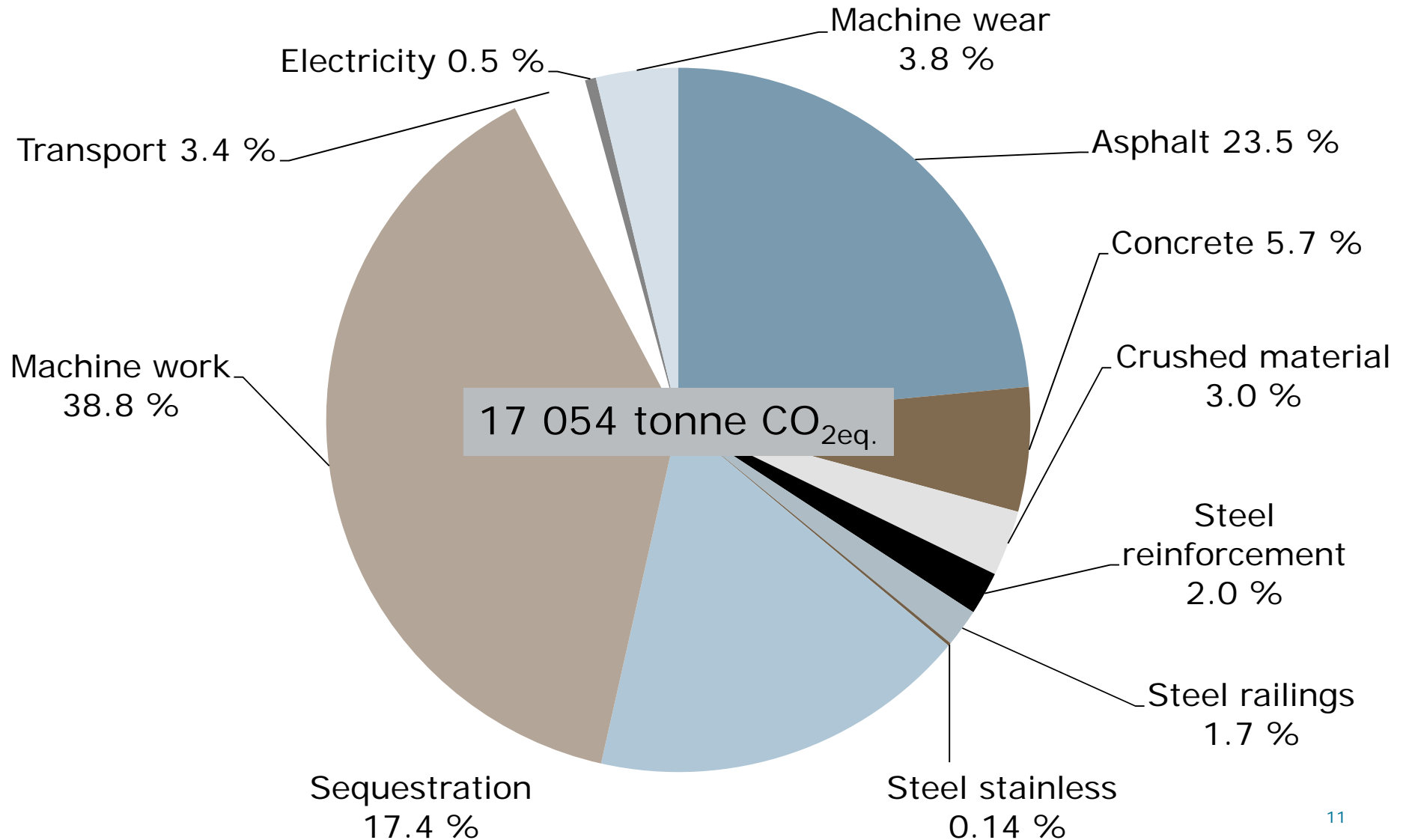
Motorway E6 Labbdalen - Skaberud

Energy use for construction activities and materials



Motorway E6 Labdalen - Skaberud

CO_{2eq.} emission for construction activities and materials





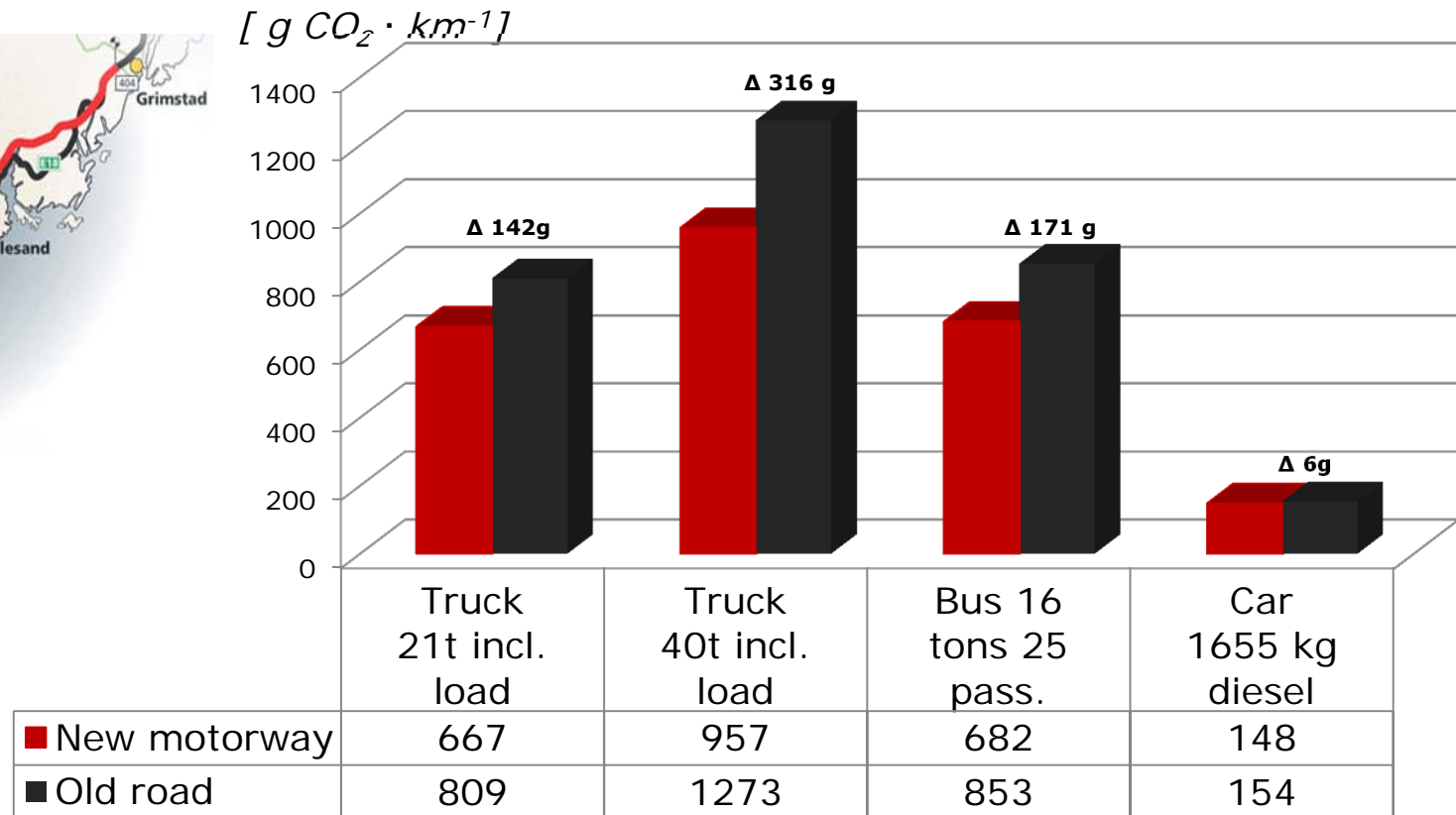
Key numbers

	E18 Sky-Langangen	E6 Labbdalen-Skaberud	Comment
Total length [km]	10.8	1.34	E6 – equivalent length as 4-fields motorway, 21 m E18: 23% tunnels, 8% bridges and more than average earthwork; 23 m
Construction costs [10 ⁶ EUR]	209	16	Without planning. Exchange rate 8NOK/EUR.
Total emission [tonne CO _{2eq.}]	56 824	4 354	During construction.
Total energy use [GWh]	190	17	The E18 had blasting work, E6 not.
Tons CO _{2eq.} per km	5 261	3 249	E6: Machine work and asphalt dominate E18: Machine work and concrete dominate
Tons CO _{2eq.} per m ²	0.23	0.15	
Tons CO _{2eq.} per 10 ⁶ EUR	272	272	By chance?
GWh/km	18	13	
MWh/ 10 ⁶ EUR	909	1 063	
Tons CO _{2eq.} /MWh	0.30	0.26	

CO_{2eq.} emission for old and new road E18 Grimstad – Kristiansand



Aust and Vest Agder,
southern part of Norway



Test is carried out during one day for both road routes (ca. 30 km) with identical vehicles and loads, but with speed adapted to conditions and regulations.

CO_{2eq.} emission from traffic per year for old and new road E18 Grimstad-Kristiansand

	Truck 21t	Truck 40t	Bus 16t	Car 1655 kg
Number per day [-]	910	260	130	11700
CO ₂ saving per km [kg/km]	0.142	0.316	0.171	0.006
Saving per day [kg/km]	129	82	22	70
Saving per year [tonne/km]	47	30	8	26

Yearly saving: **111 tonne CO_{2eq.}/km**

CO₂ pay back time: **26 years**

Input:

Construction costs, 38.3 km: 412.5*10⁶ EUR

Construction CO₂ emission: 272 tonne per 10⁶ EUR

Construction status:

PROJECT	REPORTS – CO ₂	EXPECTED CONSTRUCTION
E6 Labdalen-Skaberud	Voluntary	2012
E18 Sky-Langangen	Voluntary	2009 - 2012
Fv 465 Kvåle-Ulland	Included in contract	August 2011 – Autumn 2012
Rv 7 Sokna - Ørgenvika	Included in contract	2012- October 2014
E18 K1 Gulli-Holmene	Included in contract	2012- October 2014
E18 K2 Holmene-Tassebekk	Included in contract	2011- October 2014
E18 K3 Tassebekk -Langåker	Included in contract	2013
E18 Bommestad-Sky	Not decided	2013
E134 Gvammen – Århus	Included in contract	From 2013
Arendal Øst/Risa	Extra work	Spring 2011 – July 2013
Ringerike	Included in contract	From 2013



Conclusion



Carbon footprint factors for road construction:

- Number 1: Machine work (E18 30.6%, E6 38.8%),
- Number 2 and 3, ca. 20 %: concrete, steel reinforcement, asphalt and reduced carbon sequestration depending on project characteristics.
- The two evaluated road projects show equal CO₂ emissions during construction per invested EUR, 272 tonne CO_{2eq.} per 10⁶ EUR.
- This is a hypothesis for future work on 9 road construction contracts in Norway. Future work includes two contracts on operation & maintenance.
- It takes decades of time to equal carbon footprint consumed during construction by reduced traffic emission for new roads (even when the old one is somewhat longer and in really bad condition).

Thank you for your
attention

