Concrete pavements

for more sustainable and resilient roads in Europe

December 11th, 2019

COPave

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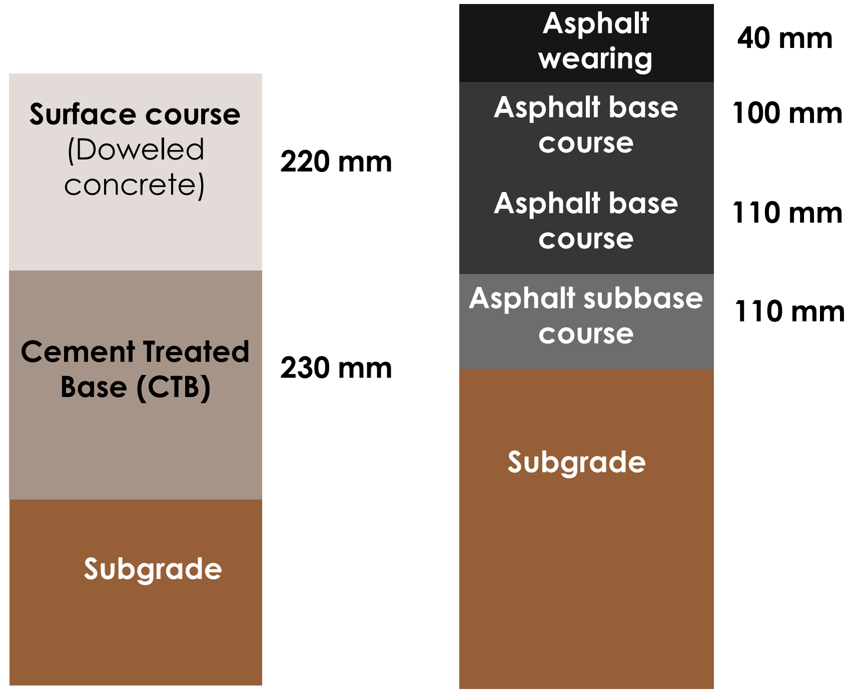
Case study description

- **Full life global warming impact:** 1 km, highway, 3 lanes, 21 m width
- **Two** different pavement designs
- Pavement design **assumptions** (ALIZE):
  - Annual daily traffic: **2780 trucks & 27800 cars/lane**
  - Growth rate: **2%**
  - Service life: **50 years**



Rigid Structure | **Flexible Structure**

Design of road maintenance schedule

The maintenance phase was included in the study using the following hypotheses:

Year	Asphalt pavement	Concrete pavement
8	100% of the wearing course area is reconstructed	
15	100% of the wearing and 1st base course are reconstructed	Grinding of 2cm of surface layer
23	100% of the wearing course area is reconstructed	
30	Major reconstruction by removing existing wearing course and adding a new asphalt base course (6cm) and wearing course (4cm) on top of the existing pavement	Major reconstruction by adding a new 10cm doweled concrete overlay on top of the existing pavement
38	100% of the wearing course area is reconstructed	
45	100% of the wearing and 1st base course are reconstructed	

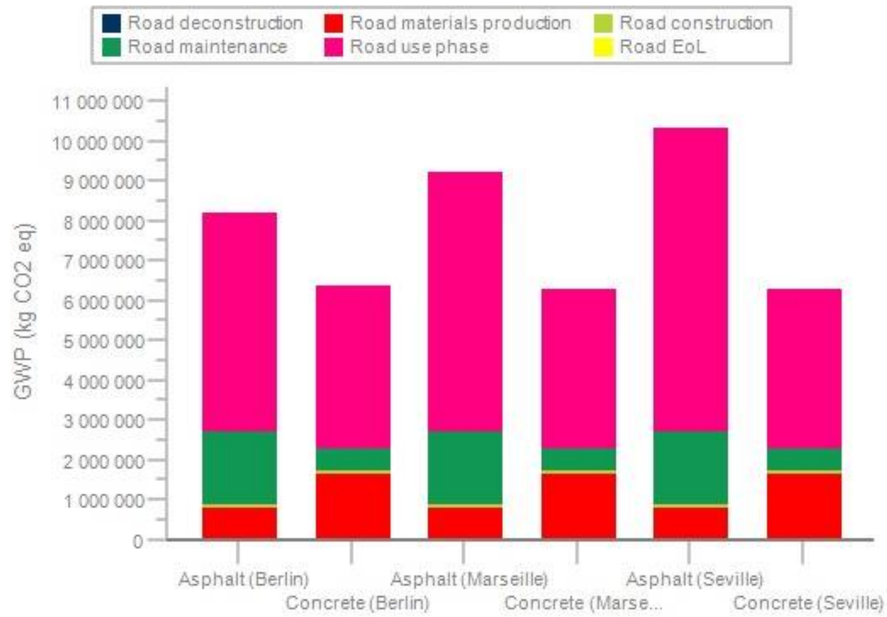
Assumptions used during use phase modelling

Use phase was simulated for 3 different locations (**Paris**, **Marseille** and **Seville**):

Modules	Design of use phase modules
Albedo	The albedo of the surface changes with time (increases for asphalt and decreases for concrete) and is restored at maintenance
Carbonation	The rigid pavement carbonates and the CEN recommendations are used for the calculations
Deflection	Asphalt pavement deflects
Roughness	The roughness of the road increases with time and is restored at maintenance
Texture	The texture of the road decreases with time and is restored at maintenance
Lighting	The road is not lit

Scale of greenhouse gas emissions reductions depend on project location

- Replacing asphalt with concrete can reduce emissions by 21 to 39%
- Switching construction of 800 km of highways/yr to concrete leads to a reduction of 12.5-29 million tn CO_2 eq. between 2020 and 2050
- This is equivalent to the annual GWP emissions of 1.4-3.3 million people in Europe

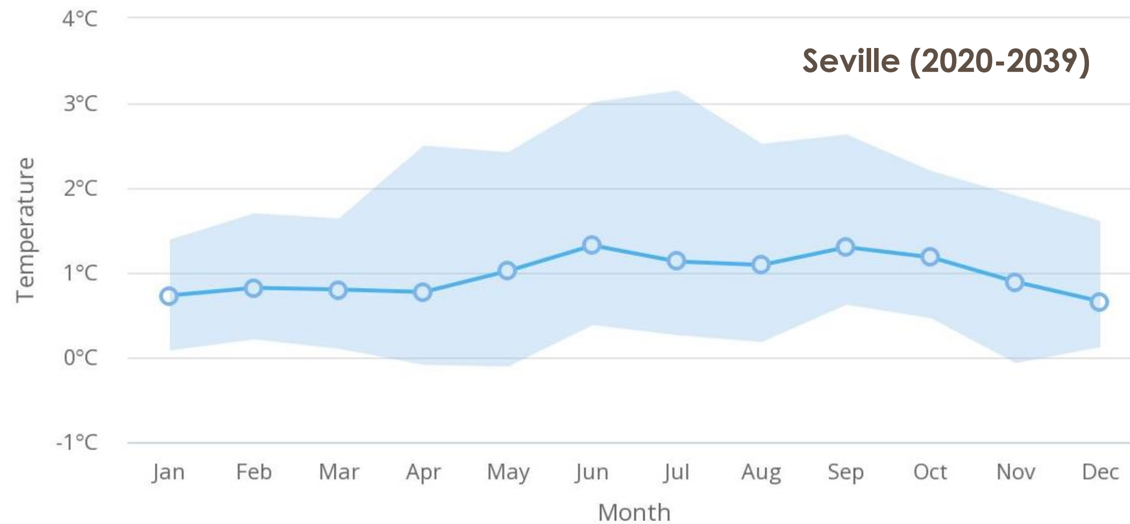


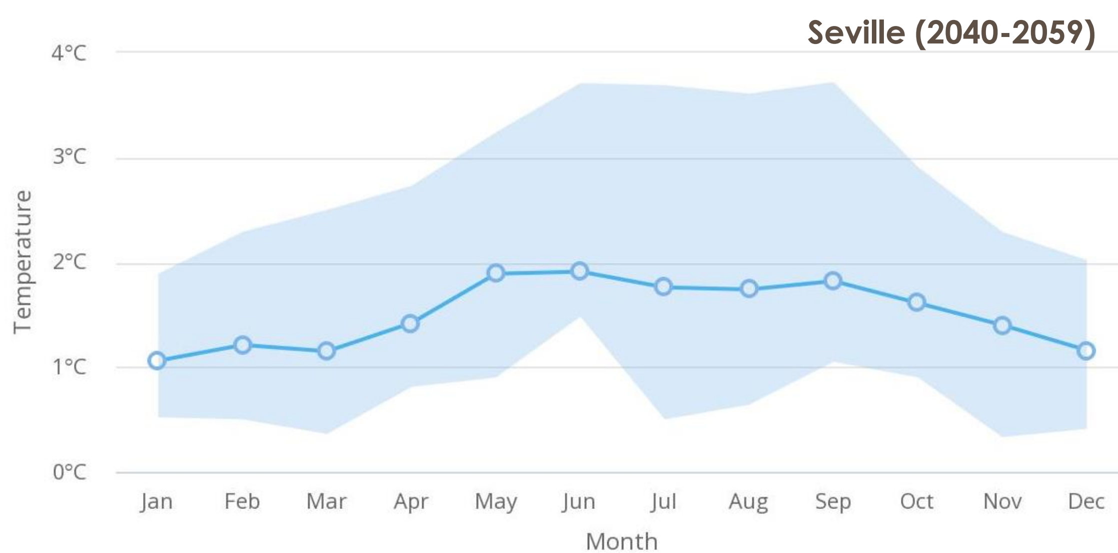
	Asphalt (Berlin)	Concrete (Berlin)	Asphalt (Marseille)	Concrete (Marseille)	Asphalt (Seville)	Concrete (Seville)
Road materials production	864	1710	864	1710	864	1710
Road construction	50	63	50	63	50	63
Road maintenance	1864	561	1864	561	1864	561
Road use phase	5417	4052	6424	3966	7531	3934
Module D	-141	-5	-141	-5	-141	-5
Total (tn CO_2 eq./km)	**8055**	**6383**	**9063**	**6297**	**10169**	**6255**
Difference	**-21%**		**-31%**		**-39%**	

Effect of climate change on ambient temperature increase

- Climate change on the ambient air temperature of Seville during 2 time periods (2020-2039 and 2040-2059) (World Bank)

- Average of all available climate models using an intermediate scenario for the evolution of GHG emissions and atmospheric concentrations





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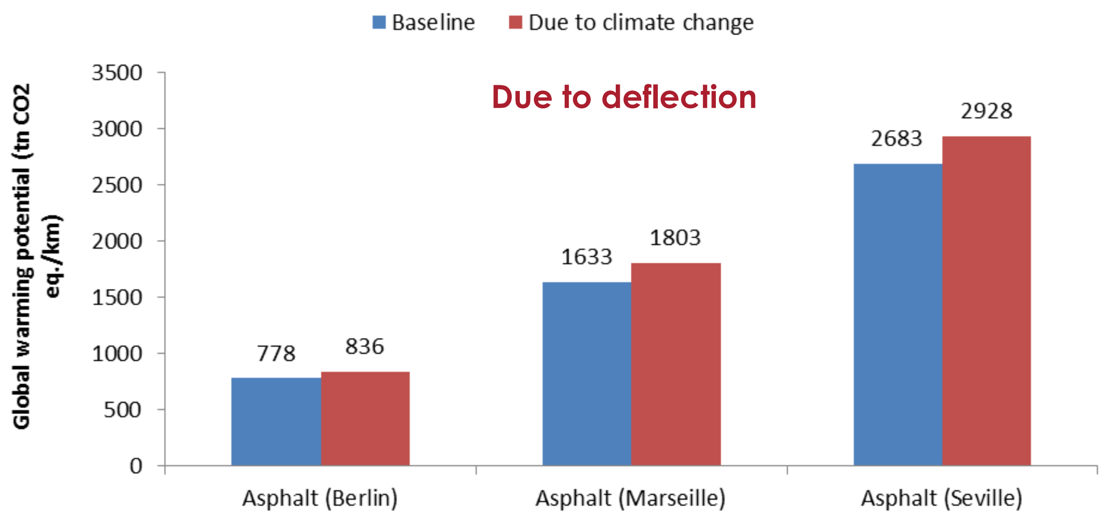
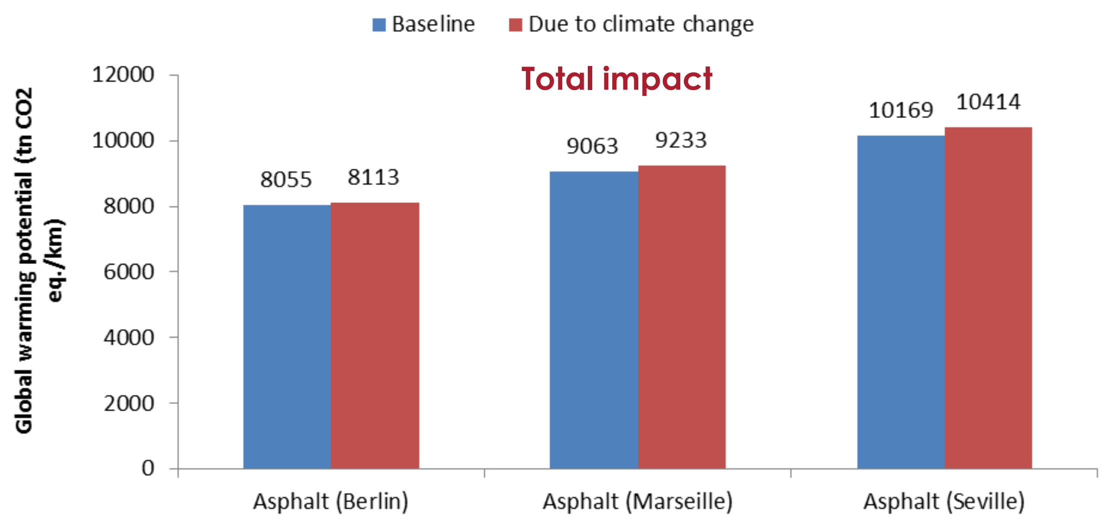
Effect of climate change on GWP results of asphalt pavements

- The 1-2°C temperature increase leads to a small increase in the total GWP for asphalt pavements due to deflection change



- Higher temperatures can cause pavement to soften and expand which can create rutting and potholes, particularly in high-traffic areas.



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Final remarks

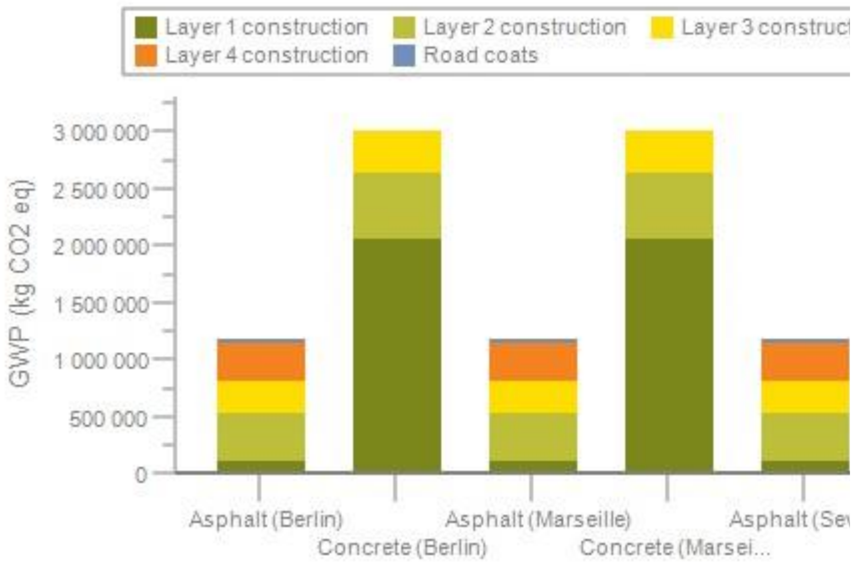
- Switching construction of European highways from flexible to rigid structure will significantly contribute in GWP reduction in the next 30 years
- Highways represent less than 5% of total road network → potential for greater contribution
- Beyond global warming, rigid structures offer higher resilience to climate change (including exceptional events) and to severe loading conditions

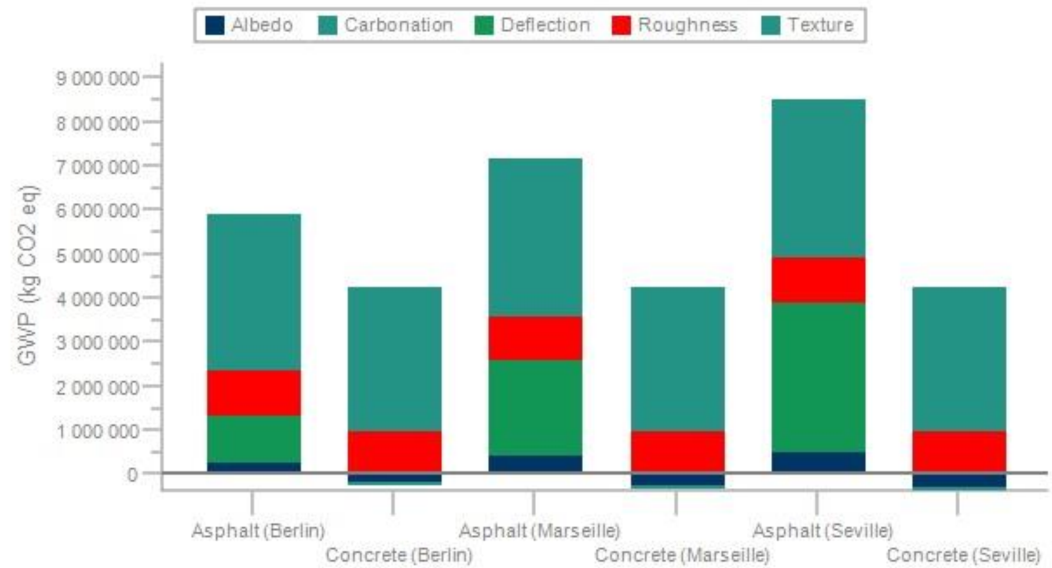
Thanks for your attention

APPENDIX

June 2019

Breakdown of emissions for construction and use phases





	Asphalt (Berlin)	Concrete (Berlin)	Asphalt (Marseille)	Concrete (Marseille)	Asphalt (Seville)	Concrete (Seville)
Layer 1 construction	111	1 122	111	1 122	111	1 122
Layer 2 construction	247	652	247	652	247	652
Layer 3 construction	274	343	274	343	274	343
Layer 4 construction	276		276		276	
Total (tn CO_2 eq.)	**915**	**1774**	**915**	**1 774**	**915**	**1 774**
Difference	**94 %**		**94 %**		**94 %**	

	Asphalt (Berlin)	Concrete (Berlin)	Asphalt (Marseille)	Concrete (Marseille)	Asphalt (Seville)	Concrete (Seville)
Albedo	269	-152	422	-239	478	-270
Carbonation		-19		-19		-19
Deflection	778		1633		2683	
Roughness	1 003	1 003	1 003	1 003	1 003	1 003
Texture	3 367	3 221	3 367	3 221	3 367	3 221
Total (tn CO_2 eq.)	**5 417**	**4 053**	**6 424**	**3 967**	**7 532**	**3 935**
Difference	**-25 %**		**-38 %**		**-48%**	

Scale of greenhouse gas emissions reductions (Berlin, Germany)

Results presented are for climate conditions similar to those in Berlin, Germany.

Yearly emissions per km of road are equal to 161 tn CO_2 eq. for asphalt (e.g. 8055 tn CO_2 eq./50 years) and 128 tn CO_2 eq. for concrete (6383 tn CO_2 eq. over 50 years)

Switching construction of 800 km of highways/yr to concrete leads to a reduction of 12.4 million tn CO_2 eq. between 2020 and 2050.

This is equivalent to the annual GWP emissions of 1.4 million people in Europe.

Year	Yearly build of highways (km)	Cumulative build of highways (km)	Yearly emissions (tn CO_2 eq.) (Asphalt; Berlin)	Yearly emissions (tn CO_2 eq.) (Concrete; Berlin)
2020	800	800	128 880	102 128
2021	800	1600	257 760	204 256
2022	800	2400	386 640	306 384
2023	800	3200	515 520	408 512
2024	800	4000	644 400	510 640
2025	800	4800	773 280	612 768
2026	800	5600	902 160	714 896
2027	800	6400	1 031 040	817 024
2028	800	7200	1 159 920	919 152
2029	800	8000	1 288 800	1 021 280
2030	800	8800	1 417 680	1 123 408
2031	800	9600	1 546 560	1 225 536
2032	800	10400	1 675 440	1 327 664
2033	800	11200	1 804 320	1 429 792
2034	800	12000	1 933 200	1 531 920
2035	800	12800	2 062 080	1 634 048
2036	800	13600	2 190 960	1 736 176
2037	800	14400	2 319 840	1 838 304
2038	800	15200	2 448 720	1 940 432
2039	800	16000	2 577 600	2 042 560
2040	800	16800	2 706 480	2 144 688
2041	800	17600	2 835 360	2 246 816
2042	800	18400	2 964 240	2 348 944
2043	800	19200	3 093 120	2 451 072
2044	800	20000	3 222 000	2 553 200
2045	800	20800	3 350 880	2 655 328
2046	800	21600	3 479 760	2 757 456
2047	800	22400	3 608 640	2 859 584
2048	800	23200	3 737 520	2 961 712
2049	800	24000	3 866 400	3 063 840
	Cumulative CO_2 emissions (tn CO_2 eq.)		**59 929 200**	**47 489 520**
	Difference (tn CO_2 eq.)		**12 439 680**	

Scale of greenhouse gas emissions reductions (Marseille, France)

Results presented are for climate conditions similar to those in Marseille, France.

Yearly emissions per km of road are equal to 181 tn CO_2 eq. for asphalt (e.g. 9063 tn CO_2 eq./50 years) and 126 tn CO_2 eq. for concrete (6297 tn CO_2 eq. over 50 years)

Switching construction of 800 km of highways/yr to concrete leads to a reduction of 20.6 million tn CO_2 eq. between 2020 and 2050.

This is equivalent to the annual GWP emissions of 2.3 million people in Europe.

Year	Yearly build of highways (km)	Cumulative build of highways (km)	Yearly emissions (tn CO_2 eq.) (Asphalt; Marseille)	Yearly emissions (tn CO_2 eq.) (Concrete; Marseille)
2020	800	800	145 008	100 752
2021	800	1600	290 016	201 504
2022	800	2400	435 024	302 256
2023	800	3200	580 032	403 008
2024	800	4000	725 040	503 760
2025	800	4800	870 048	604 512
2026	800	5600	1 015 056	705 264
2027	800	6400	1 160 064	806 016
2028	800	7200	1 305 072	906 768
2029	800	8000	1 450 080	1 007 520
2030	800	8800	1 595 088	1 108 272
2031	800	9600	1 740 096	1 209 024
2032	800	10400	1 885 104	1 309 776
2033	800	11200	2 030 112	1 410 528
2034	800	12000	2 175 120	1 511 280
2035	800	12800	2 320 128	1 612 032
2036	800	13600	2 465 136	1 712 784
2037	800	14400	2 610 144	1 813 536
2038	800	15200	2 755 152	1 914 288
2039	800	16000	2 900 160	2 015 040
2040	800	16800	3 045 168	2 115 792
2041	800	17600	3 190 176	2 216 544
2042	800	18400	3 335 184	2 317 296
2043	800	19200	3 480 192	2 418 048
2044	800	20000	3 625 200	2 518 800
2045	800	20800	3 770 208	2 619 552
2046	800	21600	3 915 216	2 720 304
2047	800	22400	4 060 224	2 821 056
2048	800	23200	4 205 232	2 921 808
2049	800	24000	4 350 240	3 022 560
	Cumulative CO_2 emissions (tn CO_2 eq.)		**67 428 720**	**46 849 680**
		Difference (tn CO_2 eq.)	**20 579 040**	

Scale of greenhouse gas emissions reductions (Seville, Spain)

Results presented are for climate conditions similar to those in Seville, Spain.

Yearly emissions per km of road are equal to 203 tn CO_2 eq. for asphalt (e.g. 10169 tn CO_2 eq./50 years) and 125 tn CO_2 eq. for concrete (6265 tn CO_2 eq. over 50 years)

Switching construction of 800 km of highways/yr to concrete leads to a reduction of 29 million tn CO_2 eq. between 2020 and 2050.

This is equivalent to the annual GWP emissions of 3.3 million people in Europe.

Year	Yearly build of highways (km)	Cumulative build of highways (km)	Yearly emissions (tn CO_2 eq.) (Asphalt; Seville)	Yearly emissions (tn CO_2 eq.) (Concrete; Seville)
2020	800	800	162 704	100 240
2021	800	1600	325 408	200 480
2022	800	2400	488 112	300 720
2023	800	3200	650 816	400 960
2024	800	4000	813 520	501 200
2025	800	4800	976 224	601 440
2026	800	5600	1 138 928	701 680
2027	800	6400	1 301 632	801 920
2028	800	7200	1 464 336	902 160
2029	800	8000	1 627 040	1 002 400
2030	800	8800	1 789 744	1 102 640
2031	800	9600	1 952 448	1 202 880
2032	800	10400	2 115 152	1 303 120
2033	800	11200	2 277 856	1 403 360
2034	800	12000	2 440 560	1 503 600
2035	800	12800	2 603 264	1 603 840
2036	800	13600	2 765 968	1 704 080
2037	800	14400	2 928 672	1 804 320
2038	800	15200	3 091 376	1 904 560
2039	800	16000	3 254 080	2 004 800
2040	800	16800	3 416 784	2 105 040
2041	800	17600	3 579 488	2 205 280
2042	800	18400	3 742 192	2 305 520
2043	800	19200	3 904 896	2 405 760
2044	800	20000	4 067 600	2 506 000
2045	800	20800	4 230 304	2 606 240
2046	800	21600	4 393 008	2 706 480
2047	800	22400	4 555 712	2 806 720
2048	800	23200	4 718 416	2 906 960
2049	800	24000	4 881 120	3 007 200
		Cumulative CO_2 emissions (tn CO_2 eq.)	**75 657 360**	**46 611 600**
		Difference (tn CO_2 eq.)	**29 045 760**	

Average temperature increase due to climate change