

Bridge Life Cycle Optimisation

Closing Seminar 14-15 May, 2012 Malmö



Introduction of new ETSI tools – Life Cycle Assessment (LCA)

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Why LCA tool in ETSI?

Bridge Life Cycle Optimisation

- Growing demand for sustainable infrastructure solutions
 - particularly regarding resource efficiency, and energy and carbon efficiency
- Life cycle thinking a required premises today, to be added to the local environmental issues
 - as normally covered in SEA and EIA of road projects
- Material and product suppliers offer LCA information
 - EPDs as basis for market competition

=> LCA likely to be mandatory during a few years
=> From early phase planning to bridge contract



Early phase planning – Route location?





Feasibility study to contract – Design?



- Assessing LCA consequences of a given bridge design, with/without a corresponding Life Cycle Plan (LCP)
- LCA method developed in ETSI based on masses



The LCA framework (ISO 14041)



- ISO 14041:2006 specifies how to carry out LCA
- Further detailed by ILCD Handbook of LCA (2010-11)
- And Product Category Rules (PCR) on how to develop Environmental Product Declarations (EPD) in Construction



Phase 1: Goal and scope definition



• What would this look like for a road bridge? (purpose, function, system boundary)



Phase 2: Life Cycle Inventory Analysis





Phase 3: Life cycle impact assessment

Bridge Life Cycle Optimisation

• Grouping and aggregating different environmental impacts is needed for decision support!





Phase 3: Life cycle impact assessment

Bridge Life Cycle Optimisation

Alternative aggregation method as decided upon in ETSI-II









The ETSI BridgeLCA tool

Bridge Life Cycle Optimisation

- ETSI definitions are used
 - Bridge system and elements
 - Bridge life cycle plan
- State-of-the-art LCA methodology is used
 - ILCD Handbook of LCA
 - PCR for Constructions
 - Ecoinvent v2 LCA database (default emission values)
- Excel model
 - Prepared for using national specific or project specific emission data
 - Calculating selected midpoint-level environmental impact categories, and normalized and weighted results
 - Calculating energy consumption
 - User friendliness and flexibility (ETSI-II recommendations)



BridgeLCA Input: Major and minor impact materials

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16			1.5 C55/67 "Element Concrete" 1.6 Self Compacting Concrete SCC C55/67	XC3, XC4, XF4; CEM II/A-LL XC4, XS3, XF4; CEM II/A-LL	. m3								-	1												_
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BridgeLCA Input: Transportation of materials

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BridgeLCA Input Traffic Sheet (due to bridge closure)

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ETSI Extra traffic generation model

Bridge scenario	Graphic	Description			
0	$\begin{array}{c} B \\ \star \end{array} \begin{array}{c} C \\ B \end{array}$	Bridge is closed, all traffic goes through detour path	Traffic Load Congested	Decription At low speeds, traffic will have high RPM/rapid gear change due to start- stop motion. This causes high fuel consumption.	Graphic image
1	$\begin{array}{c c} B \rightarrow D \\ \hline \uparrow & \checkmark \\ A \leftarrow C \end{array}$	Bridge is open one way, other traffic takes detour path	Average Free Flowing	Average traffic (40-70 km/h) will have smooth motion/little gear change. Low RPM/high gears lead to low fuel consumption for most vehicles High speed traffic (>70 km/h) will have slightly	
2	B × D ↓ × × A × C	Bridge is open both ways, no traffic uses detour path		higher RPM than average traffic, and therefore higher fuel consumption.	 16



BridgeLCA Impact matrix (Ecoinvent or other data)

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	Emission data source:	Norway	_	Observational antication	and an and a second second				
				Climate change	Ozone depletion	Terrestrial acidification	Freshwater eutrophicatio	Fossil depletion	Human toxicity, cancer
	Material	Quality		kg CO2 eq	kg CFC-11 eq	kg SO2 eq	kg P eq	kg oil eq	CTUh
	1. Concrete	1.1 C25/30	m3	2,61E+02	8,84E-06	6 4,44E-01	1,37E-02	2,57E+01	1,11E-0
		1.2 C30/37	m3	2,89E+02	9,77E-06	5 4,98E-01	1,56E-02	2,93E+01	1,23E-0
		1.3 C45/55	m3	2,89E+02	9,77E-06	6 4,98E-01	1,56E-02	2,93E+01	1,23E-0
		1.4 C55/67	m3	2,89E+02	9,77E-06	5 4,98E-01	1,56E-02	2,93E+01	1,23E-0
		1.5 C55/67 "E	m3	2,89E+02	9,77E-06	6 4,98E-01	1,56E-02	2,93E+01	1,23E-0
ials		1.6 Self Comp Close Full Screen C55/6/	ma	2,89E+02	9,77E-00	4,98E-01	1,56E-02	2,93E+01	1,23E-0
ater	2 Construction Steel	2.1 C255NI	top	4,04E+02	1,46E-0	8,77E-01	8,54E-02	6,77E+01	2,85E-0
Ĕ	2. Construction Steel	2.1.000014	ton	1,09E+03	5,89E-0	0,02E+00	1,11E+00	0,15E+02	2,25E-0
pac		2.4.1.4301	ton	4,72000	2,335-04	2,200+01	2,300+00	1,400+03	3,71E-0
Ē		2.5 S355K2W (weathering steel)	ton	1,89E+03	5,89E-05	6,02E+00	1,11E+00	6,15E+02	2,25E-0
5	3. Reinforcement steel	3.1 A500HW	ton	1,45E+03	6,01E-05	5 4,74E+00	8,72E-01	4,81E+02	2,03E-0
L L		3.2 B600KX (1.4301) Cold-rolled	ton	4,72E+03	2,33E-04	4 2,20E+01	2,30E+00	1,40E+03	3,71E-0
Maj	A Prostronging steel	3.3 B600KX (1.4301) Hot-rolled	ton	4,72E+03	2,33E-04	4 2,20E+01	2,30E+00	1,40E+03	3,71E-0
	4. Presuessing steel	4.2 Cables (Cable staved and Suspension bridges)	ton	1,45E+03	6.01E-05	5 4,74E+00	8.72E-01	4,81E+02	2,03E-0
	5. Timber	5.1 Sawn timber	m3	8,54E+01	8,04E-06	6 4,87E-01	4,33E-02	2,83E+01	3,01E-0
		5.2 Glue laminated timber	m3	2,23E+02	2,19E-05	5 1,30E+00	1,20E-01	7,90E+01	4,90E-0
	6. Asphalt	6.1 Asphalt concrete [AC 16/120] 6.2 Stone Mastic Asphalt [SMA 16/20]	m3	2,10E-01 2,10E-01	8,17E-08	5,72E-04	1,45E-05	1,56E-01	4,47E-1
		6.3 Polymer Modified Mastic Asphalt [PMMA 16/80]	m3	2,10E-01	8,17E-08	5,72E-04	1,45E-05	1,56E-01	4,47E-1
	7. Waterproofing	7.1Asphalt membrane (double) (thickness 20 mm)	m2	1,16E+00	3,62E-07	7 5,76E-03	9,49E-04	1,13E+00	3,38E-1
s		7.2 Epoxy (thickness 6 mm)	m2	2,72E+00	3,22E-08	3 1,56E-02	9,06E-05	1,16E+00	6,69E-1
lial		7.3 Rubberized bitumen lotion (0,2 kg/m2)	m2	4,05E-01	1,91E-07	7 2,61E-03	1,23E-04	6,17E-01	2,75E-1
nate		7.5 Polyurethane (thickness 8 mm)	m2	4.31E+00	1,18E-07	7 1.61E-02	5.76E-04	2.10E+00	2.84E-1
ะ ช	8. Others	8.1 Zinc coating (100 μm)	m2	6,20E+00	7,83E-07	7 5,24E-02	7,12E-03	1,96E+00	2,02E-0
ba		8.2 Paint EPZn(R)EPPUR320/5-FeSa 2(1/2) (thickness 320 µm)	m2	6,72E+00	6,91E-08	3,87E-02	2,09E-04	2,88E+00	7,26E-1
Li V		8.3 Glass	kg	9,79E-01	8,82E-08	3 7,84E-03	1,42E-04	2,76E-01	1,57E-1
L L		8.5 Salt impregnation (10kg/m3)	m3	3.13E+00	1.24E-06	5 2.18E-02	5.08E-03	1.33E+00	7,81E-1 7,85E-0
DC		8.6 Acryl (Plexiglass)	m3	8,38E+00	4,10E-09	3,75E-02	3,35E-04	3,13E+00	4,25E-1
ž		8.7 Polycarbonate (Plexiglass)	m3	7,78E+00	2,58E-06	6 2,25E-02	2,11E-04	2,38E+00	6,20E-1
		8.8 Plastic (PEH) 8 X	kg	1,93E+00 0,00E+00	7,08E-10	0 5,91E-03 0 00E+00	2,69E-05 0.00E+00	1,70E+00 0.00E+00	1,49E-1 0.00E+0
	9. Energy	9.1 Diesel	1	0.091554292	1,14093E-08	0.000741726	4,51E-06	0.032129875	7.30594E-1
		9.2 Electricity	kwh	0,170437939	1,25297E-08	0,000434949	3,41E-05	0,043887538	7,11843E-1
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raci	10. Blasting	10.1 Blasting	m3	2,519070706	1,7189E-0	0,339290367	5,53E-04	0,541465272	1,09388E-1
Ĭ	Transportation	11.2 Material transportation truck	tkm	0,010715159	2 64968E-08	0,000218016	1,072-00	0,003639569	3 62105E-1
Ē		11.3 Material transportation train	tkm	0,039440346	2,859E-09	0,000205203	2,51E-05	0,011982495	2,23969E-1
le le		11.4 Transportation car	pkm	0,180947278	2,4488E-08	0,000593933	2,5173E-05	0,062963828	5,79262E-1
0		11.5 Petrol fuel consumption, Passenger vehicle mixed fleet	kg	3,360251	9	0,00362	0	0	
		The Dieser rue consumption, venicle mixed fleet	ĸg	3,36724		0,012	0	0	
	Concrete	Landfill	m3	1 745+01	5 235-00	6 1.08E-01	1 38E-03	1 11E+01	3 145-0
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BridgeLCA TŠI Ecoinvent, national or project specific data

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3										. In
4					Climate cha	ange (GWP)		-	-	4
5			Unit	Ecoinvent	Denmark	Finland	Norway	Sweden	Product spesific	
			ed							
		Close Full Screen	02	-	-	_		-	_	
6	Motorial	Quality	0							
0			¥ Kar/ma2	0	S	S	S	S	ى N	4
0	1. Concrete	1.1 C25/30	kg/m3	2,01E+02						
0		1.2 030/37	kg/m3	2,89E+02						
9		1.3 C45/55	kg/m3	2,89E+02						-
10		1.4 C55/67	kg/m3	2,89E+02						-
11		1.5 C55/67 "Element Concrete"	kg/m3	2,89E+02				-		
12		1.6 Self Compacting Concrete SCC C55/67	kg/m3	2,89E+02						
13		1.7 Reinforced concrete pile C40/50	kg/m3	4,04E+02						
14	2. Construction Steel	2.1 S355NL	kg/ton	1,89E+03						4
15		2.2 1.4404	kg/ton	4,72E+03						
16		2.3 1.4301	kg/ton	4,72E+03						
17		2.4 S355K2W (weathering steel)	kg/ton	1,89E+03						
18	3. Reinforcement steel	3.1 A500HW	kg/ton	1,45E+03						
19		3.2 B600KX (1.4301) Cold-rolled	kg/ton	4,72E+03						
20		3.3 B600KX (1.4301) Hot-rolled	kg/ton	4,72E+03						-
21	4. Prestressing steel	4.1 St 1640/1860	kg/ton	1,45E+03						
22	C. Timber	4.2 Cables (Cable stayed and Suspension bridge	kg/ton	1,45E+03						
23	5. Timber	5.1 Sawn timber	kg/m3	8,54E+01						
24	6 Apphalt	5.2 Glue laminated timber	kg/m3	2,232+02			1			
25	o. Asphalt	6.2 Stone Mastic Asphalt [SMA 16/20]	kg/m3	2,10E-01						-
27		6.3 Polymer Modified Mastic Asphalt [PMMA 16/	kg/m3	2,10E-01						1
28	7 Waterproofing	7 1Asphalt membrane (double) (thickness 20 m	kg/m2	1.16E+00						
29		7.2 Epoxy (thickness 6 mm)	kg/m2	2.72E+00						1
30		7.3 Rubberized bitumen lotion (0,2 kg/m2)	kg/m2	4,05E-01						1
31	Front Page Input sheet Input tra	T 4 Asphalt Mastic (thickness 20 mm)	ka/m2		ET Ecoinver	t Energy Menus	Set CarFleet	1		1

BridgeLCA ETSI Results: Size of environmental impact

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000			📄 Bric	dge LCA test for gammel PC.xls				
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1 2 3 4	AGGREGATED RESULTS Overall LCIA results - Midpoin	t results / Normalized re	sults / Weighted resul	ts				
5	Emission category	Equivalent	Method	Midpoint results (ka ea.)	Normalised (PE)	Weighted (PE)		
6	Climate change	GWP kg CO2 eg	ReCiPe	1,29E+05	1.15E+01	1,15E+01		
7	Ozone depletion	ODP kg CFC-11 eg	ReCiPe	5.56E-03	2.53E-01	2.53E-01		
8	Terrestrial acidification	AP kg SO2 eg	ReCiPe	4.45E+02	1.29E+01	1,29E+01		
9	Freshwater eutrophication	EP kg P eq	ReCiPe	5,30E+01	1,28E+02	1,28E+02		
10	Fossil depletion	kg oil eg	ReCiPe	3,49E+04	2,10E+01	2,10E+01		
11	Human toxicity, cancer	Ose Full Screen CTUh	USEtox	3,95E-05				
12	Human toxicity, non-cancer	HTNC CTUh	USEtox	5,56E-06				
13	Ecotoxicity	ETX CTUe	USEtox	1,06E+03				
14								
15	Midpoint I CIA results - Distrib	uted over bridge life over	le stages					
15	Emission esteren	Led over bridge me cyc	Mathad	Motorial Draduction	Construction	OPSM	EQI Total	
17	Climate change	CW/P kg CO2 og	BaCiBa	Material Production	4 37E+02	1 415+04	2 26E+02 1 20E+05	
18	Ozono deplotion	ODP kg CEC 11 og	ReciPe	5 475-03	5.875.05	2 845 05	3 885.06 5 565.03	
10	Terrestrial esidification	AD kg CFC-11 eq	Recipe	2,005+02	1,672-00	2,04E-00	1465+00 4455+00	
20	Freehuster outraphication	Kg SO2 eq	Recipe	5,992+02	E 72E 02	4,245-01	1,402100 4,452102	
20	Freshwater eutrophication	ADD kg P eq	Recipe	5,292+01	5,73E-02	2,032-02	1,702-02 5,302+01	
21	Human taxisity server	ADP Kg Sb eq	Recipe	3,402+04	1,522+02	7,34E+01	3,492+04	
22	Human toxicity, cancer		USEIOX	3,922-05	1,20E-07	0,30E-00	3,34E-08 3,95E-05 8,57E-09 5,56E-06	
24	Ecotoxicity	ETX CTUS	USEtox	1.05E+03	9 12 - 01	4.465-01	5.98E-01 1.06E+03	
25	Ecoloxicity		OSEIOX	1,052103	3,122-01	4,402-01	3,302-01 1,002.03	
26								
27 28	Normalised L	CIA results			Relative midpoint L	CIA results		
29	2.005+02		100 %					
30	2,002+02		100 %				= EOL	
31	1 80E+02		98.94					
32	1,002102		56 /6				OR&M	
33	1.60E+02		05.9					
34	1,002.02		90 %				Construction	
35	- 140E+02							
30			5D 94 %				Material Production	
37	¥ 1.20E+02							
30			EP 92 %					
39	1.00E+02		AP					
41	<u>g</u>		90 %					
41	5 8.00F+01		ODP					
42	2		GWP 88 %					
43	6.00E+01							
45	0,000.01		86 %					
46	4.00E+01							
47	,,		84 %					
48	2.00F+01		Constant of the second s					
49	2,502.01		82 %					
50	0.00E+00			GWP ODP AP	FP ADP	HTC HTNC	FTX	
51						ine inte		
14 4 P PI	Front Page Input sheet Input traffic Resu	Its Results energy Impact mat	rix GWP ODP AP	EP FD HTC HT	NC _ ET _ Ecoinvent _ En	ergy MenuSet CarFlee	et]	00



BridgeLCA Results: Size of environmental impact





BridgeLCA Results: Size of environmental impact



ETSI Results: Causes of impacts

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131		DET	AILED RESULTS	 Midpoint value 	ues (witho	out Norma	alization and W	eighting)			
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122					0.475		Material				_
133			GWP		GWP		Production	Construction	UR&M	EOL	PI
135		100 %		Concrete	Concrete		13 68 %	0.00 %	0.00 %	0.00 %	eu
136		80 %		Construction steel	Constructio	on steel	42.73 %	0.00 %	0.00 %	0.00 %	
137		60 %	Close F	ull Screen inforcement steel	Reinforcem	nent steel	11.22 %	0.00 %	0.00 %	0.00 %	
138		40 %		Prestressing steel	Prestressin	g steel	0,00 %	0,00 %	0,00 %	0,00 %	
139		20 %		Timber	Timber		14,02 %	0,00 %	0,00 %	0,00 %	
140		0%		Asphalt	Asphalt		0,00 %	0,00 %	0,00 %	0,15 %	
141			tos Me non non	Waterproofing	Waterproof	ing	0,21 %	0,00 %	0,00 %	0,00 %	
142		60,00	JCC STRUCE ORC	Others	Others		3,89 %	0,00 %	0,00 %	0,00 %	
143		rialPlu	Con	Energy	Energy		0,00 %	0,03 %	0,01 %	0,02 %	
144		Nate.		Blasting	Blasting		0,00 %	0,00 %	0,00 %	0,00 %	
145					Transporta	tion	2,79 %	0,31 %	10,94 %	0,00 %	
140				. Concerns]		Material		1	1	
147			ODP	Concrete	ODP		Production	Construction	OR&M	EOL	P
148				Construction steel			%	%	%	%	ec
149		100 %		Reinforcement steel	Concrete		10,73 %	0,00 %	0,00 %	0,00 %	
150		80 %		Prestressing steel	Constructio	on steel	30,95 %	0,00 %	0,00 %	0,00 %	
151		40 %		Timber	Reinforcem	nent steel	10,81 %	0,00 %	0,00 %	0,00 %	
152		20 %		Asphalt	Prestressin	ig steel	0,00 %	0,00 %	0,00 %	0,00 %	
153		0%		Waterproofing	Timber		31,62 %	0,00 %	0,00 %	0,00 %	
154			10, Mrs Par Tar		Asphalt		0,02 %	0,00 %	0,00 %	0,00 %	
155		3	Juct struct ORD E	= Others	Vvaterproof	ing	1,49 %	0,00 %	0,00 %	0,00 %	
157		(a)PI	CON	Energy	Enorgy		2,49 %	0,00 %	0,00 %	0,00 %	
158		Mate.		Blasting	Blasting		0.00 %	0,00 %	0,00 %	0.00 %	
159				Transportation	Transportat	tion	10.24 %	0.97 %	0.48 %	0.00 %	
160					1						
			AP				Material				
161					AP		Production	Construction	OR&M	EOL	Pi
162		100 %		Concrete			%	%	%	%	ec
163		80 %		Construction steel	Concrete		6,74 %	0,00 %	0,00 %	0,00 %	
164		60 %		Reinforcement steel	Constructio	on steel	39,53 %	0,00 %	0,00 %	0,00 %	
165		40 %		Prestressing steel	Brootrocer	ient steel	10,67 %	0,00 %	0,00 %	0,00 %	
167		20 %		Timber	Timbor	ig steel	23.57 %	0,00 %	0,00 %	0,00 %	
168		0%		Asphalt	Asphalt		23,57 %	0,00 %	0,00 %	0,00 %	
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ETSI Results: Causes of impacts

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141	00.0/					Construction st	teel	0,00 %	0,00 %	
142	80 %							0,00 %	0,00 %	
143						Reinforcement	stool	0,01 %	0,02 %	
144	60 %					- Kennorcement	steer	0,00 %	0,00 %	
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146	10.04					Prestressing ste	eel			
147	40 %							OR&M	FOL	P
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149	20 0/					Timber		0.00 %	0.00 %	
150	20 %							0,00 %	0,00 %	
151						Acabalt		0,00 %	0,00 %	
152						- Asphalt		0,00 %	0,00 %	
153	0 /0							0,00 %	0,00 %	
154				•		Waterproofing		0,00 %	0,00 %	
155		. ~	30.	1	\sim	Materproofing		0,00 %	0,00 %	
157		X ¹⁰	X A	` {	\mathcal{S}			0,00 %	0,00 %	
158		NUC N	y or			Others		0.00 %	0.00 %	
159			•					0,48 %	0.00 %	
160		in the				Energy				
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168								0.00 %	0.27 %	
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BridgeLCA ETSI Results: Energy consumption

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23		RESULTS FROM	ENERGY CALCULATIO	NS		7								
4		Energy	Unit	MJ	%									
5 6 7		Non-renewable energy	Fossil energy Nuclear Biomass (NR)	2,56E+06 2,85E+05 3,22E+00	61,7 % 6,9 % 0,0 %) }								
8 9 10		Renewable energy	Biomass (R) Wind, solar, geothermic Hydropc	1,26E+06 5,28E+03 4,31E+04	30,3 % 0,1 % 1,0 %									
11		Total	Close Full Screen	4,15E+06	100,0 %									
12														
14			Energy consumption (MJ)							1				
						1.01		Wind, solar,						
15		Material / activity	9 78E+04	7.28E+04	1 95E+04	Biomass (NR) 2 37E-01	Biomass (R) 6 17E+02	geothermal 6.64F+01	4 76E+03	-				
17		Construction Steel	8,31E+05	7,54E+05	5,86E+04	3,59E-01	5,02E+03	1,06E+03	1,16E+04					
18		Reinforcement steel	2,31E+05	2,02E+05	2,34E+04	1,21E-01	1,57E+03	4,28E+02	3,84E+03					
19		Prestressing steel	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00					
20		Timber	1,59E+06	2,64E+05	7,77E+04	7,40E-01	1,24E+06	1,32E+03	9,95E+03					
21		Waterproofing	1,94E+05	1,80E+05	9,31E+03	4,88E-01	1,89E+03	5,38E+01	2,11E+03					
23		Others	3.32E+05	2.89E+05	3.61E+04	9.18E-02	2.11E+03	5.42E+02	4.41E+03					
24		Energy	2,77E+04	2,70E+04	5,38E+02	3,57E-02	2,30E+01	9,97E+00	7,24E+01					
25		Blasting	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00					
26		Transportation	3,08E+05	2,98E+05	8,33E+03	5,00E-01	2,85E+02	1,02E+02	1,27E+03					
27		Sum	4,15E+06	2,56E+06	2,85E+05	3,22E+00	1,26E+06	5,28E+03	4,31E+04					
28										ר				
30			Energy carriers (share of consu	mption)		Energy for	materials/activi	ities						
32			1%				%	Con	crete					
33			0%			9%		Con	struction Steel					
35						1%		Beir	oforcement steel					
36				Fossil energy		8%	20 %	Pro	stressing steel					
37		30 %		Nuclear				= Pie	scressing sceer					
30				Biomass (NP)		13 %		Tim	ber					
40				- biomass (INK)			6 %	6 Asp	halt					
41				Biomass (R)				0% Wat	terproofing					
42			62 %	Wind, solar, ge	othermic	5%		= Orth						
43		0% 7%		Hydropower				= Oth	ers					
45							38 %	= Ene	rgy					
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ETSI Results: Energy consumption



ETSI Results: Energy consumption

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Conclusions and recommendations

Bridge Life Cycle Optimisation

- BridgeLCA covers all the most important LCA issues for road bridges
 - The tool is flexible for use at various stages of the bridge planning and design process
 - Relevance of the life cycle phases
 - Materials production is well covered
 - Construction phase needs good empirical data input!
 - OR&M phase needs inputs from a good bridge life cycle plan
 - EOL phase is probably not very important
 - Recommendations
 - BridgeLCA to be tested on variety of bridges
 - Empirical data and experience to be collected
 - Database to be systematically improved