LCA of selected road bridges in Norway

Johanne Hammervold
Senior Advisor
johanne@misa.no
Phone: 411 20661
www.misa.no

NTNU
Norwegian University of Science and Technology

Outline

- Presentation of case bridges
  - Bridge types
  - Materials included
- Results
  - Totals
  - In more detail for global warming and acidification
- Conclusions

- MiSA case study
  - Comparison of three bridges for one bridge site

The case bridges

- 21 concrete bridges
  - 6 box girder bridges, 4 girder bridges, 9 slab bridges
- 9 steel bridges
  - 6 girder bridges, 1 arch bridge, 1 box bridge, 1 slab bridge
- 5 timber bridges
  - 4 arch bridges, 1 of unknown design

Size parameters – Concrete bridges

NAME	TYPE	Width	Length	Area	Spans	Max hight
	Unit	m	m	m^2	No	m
Brattfoss East bridge	Concrete box girder	11	231	2 541		
Hillersvika bridge	Concrete box girder	10.6	38.5	417	1	ca 10
Hobekk bru	Concrete box girder	10.5	160	3 395	3	ca 30
Kjosevegen bru	Concrete box girder	10.5	307	6 447	5	ca 60
Seimsbrui bridge	Concrete box girder	10.3	26	372		
Svelgjabrui bridge	Concrete box girder	8.5	40	340		
Myklebust bridge	Concrete girder	6.5	22	143		
Sifjordbotn bridge	Concrete girder	6.5	14	91		
Stigagjel bridge	Concrete girder	4	35	140		
Solli bridge	Concrete girder	13	112	1 456	4	ca 15
Gulliksrud bridge	Concrete slab	12	183	2 196		
Henriksåsen bru	Concrete slab	10.5	55	1 188	3	ca 15
Hofsroed bru	Concrete slab	10.5	103	2 201	3	ca 15
Holten bridge	Concrete slab	8.9	24	214		
Jordola bridge	Concrete slab	8.9	24.5	218		
Selli bridge	Concrete slab	14	30	420		
Solum bru	Concrete slab	10.5	180	3 834	6	ca 25
Struten bru	Concrete slab	10.5	67	1 444	2	ca 25
Kalnes bridge	Concrete slab	10.25	60.19	800	3	ca 27

Size parameters – Steel and Timber bridges

NAME	TYPE	Width	Length	Area	Spans	Max hight
	Unit	m	m	m^2	No	m
Austerstraumen bridge	Steel girder	9.9	196	1 940		
Breivikeidet bridge	Steel girder	8.1	35	284		
Klenevaagen bridge	Steel girder	8.3	42.2	321	1	20
Noetoey bridge	Steel girder	6.5	106	689		
Vesterbukta bridge	Steel girder	9.9	196	273		
Vesterstraumen bridge	Steel girder	9.9	305	3 020		
Aasnes bridge	Steel arch	9	111	1 120	1	?
Namsos bridge	Steel box girder	11	360	3 960		
Spissoey bridge	Steel slab	6.5	72	468		

NAME	TYPE	Width	Length	Area	Spans	Max hight
	Unit	m	m	m^2	No	m
Fretheim bridge	Timber arch	6.05	37.9	230	1	ca 5
Maasoer bridge	Timber arch			754		
Ner-Hole bridge	Timber arch	6.5	46.9	305	1	ca 8
Nybergsund bridge	Timber arch			1 139		
Borlange bridge	Timber, unknown design			164		

Materials included in study

Amounts are mainly based on tender documents

OM and EOL not included

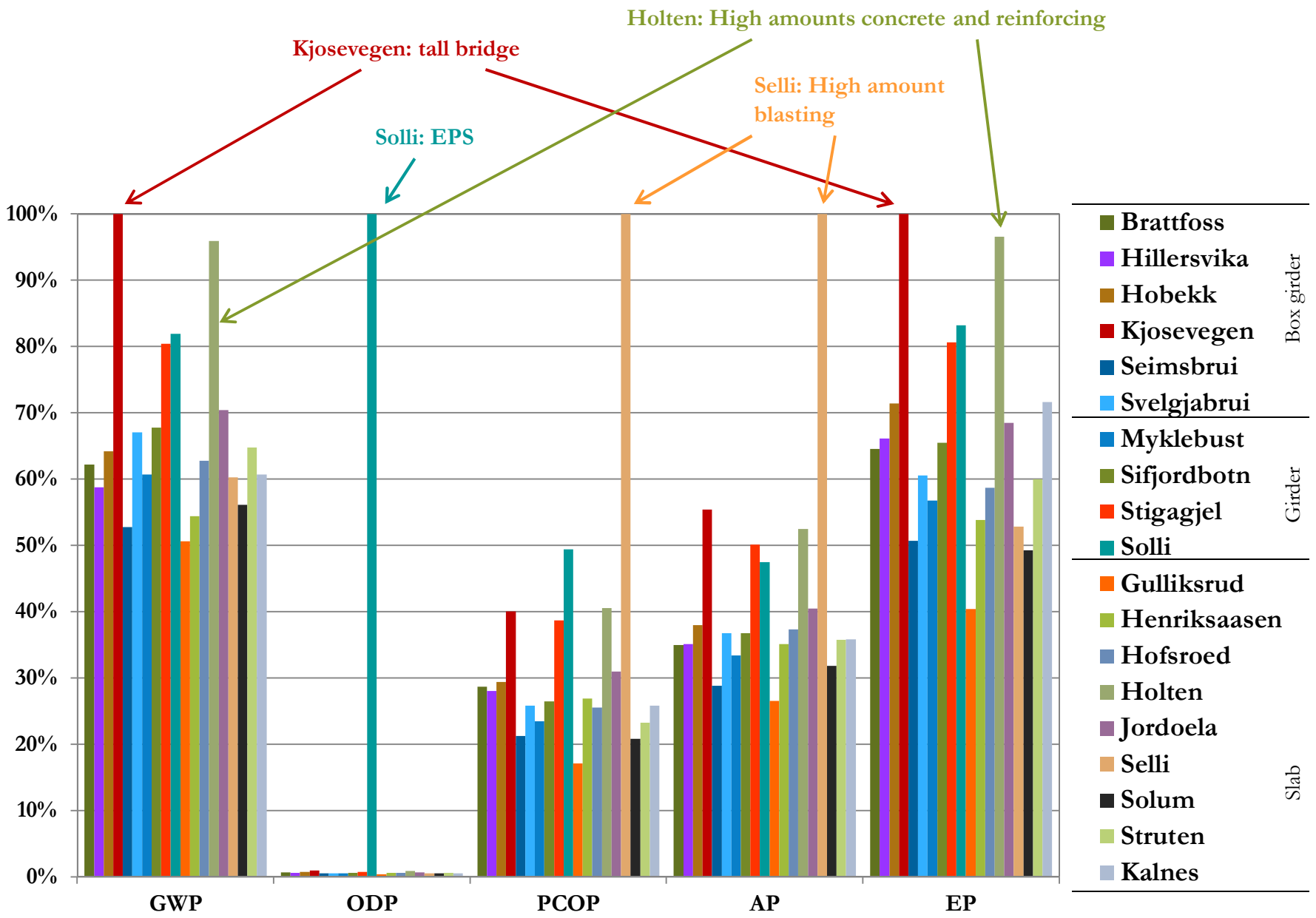
	Blasting	Excavation	Machinery	Geotextile	EPS	Cement mortar	Concrete	Reinforcing	Mastic asphalt	Glulam	Sawn timber	Preservative tr.	Copper	Steel	Powder coating	Zinc coating	Asphalt mem.	Tack coat	Asphalt
Concrete bridges																			
Brattfoss East bridge	x		x				x	x						x	x	x	x	x	x
Hillersvika bridge	x	x	x				x	x						x	x	x	x		x
Hobekk bridge	x		x			x	x	x	x					x	x	x	x		x
Kjosevegen bridge			x				x	x						x	x	x	x		x
Seimsbrui bridge			x				x	x						x	x	x	x	x	x
Svelgjabrui bridge	x		x				x	x						x	x	x	x	x	x
Myklebust bridge	x		x				x	x						x	x	x	x	x	x
Sifjordbotn bridge	x		x				x	x						x	x	x	x	x	x
Stigagjel bridge	x		x				x	x						x	x	x	x	x	x
Solli bridge		x	x	x	x		x	x						x	x	x	x		x
Gulliksrud bridge	x		x				x	x						x	x		x	x	x
Henriksaasen bridge	x		x				x	x	x					x	x	x	x		x
Hofsroed bridge	x		x				x	x	x					x	x	x	x		x
Holten bridge	x		x				x	x						x	x	x	x	x	x
Jordola bridge	x		x				x	x						x	x	x	x	x	x
Selli bridge	x		x				x	x						x	x	x	x	x	x
Solum bridge	x		x				x	x	x					x	x	x	x		x
Struten bridge			x			x	x	x	x					x	x	x	x		x
Kalnes bridge		x	x	x			x	x						x	x	x	x		x
Steel bridges																			
Aasnes bridge	x	x	x				x	x						x	x	x	x		x
Namsos bridge			x				x	x						x	x	x	x	x	x
Austerstraumen bridge	x		x				x	x						x	x	x	x	x	x
Breivikeidet bridge			x				x	x						x	x	x	x	x	x
Klenevaagen bridge	x	x	x				x	x						x	x	x	x		x
Noetoey bridge	x		x				x	x						x	x	x	x	x	x
Vesterbukta bridge	x		x				x	x						x	x	x	x	x	x
Vesterstraumen bridge	x		x				x	x						x	x	x	x	x	x
Spissoey bridge	x		x				x	x						x	x	x	x	x	x
Timber bridges																			
Fretheim bridge		x	x				x	x		x	x	x		x	x	x			x
Maasoer bridge		x	x				x	x		x	x	x	x	x			x	x	x
Ner-Hole bridge			x				x	x		x	x	x	x	x			x	x	x
Nybergsund bridge							x	x		x	x	x	x	x			x		x
Borlange bridge			x				x	x		x	x	x		x					x

Environmental performance

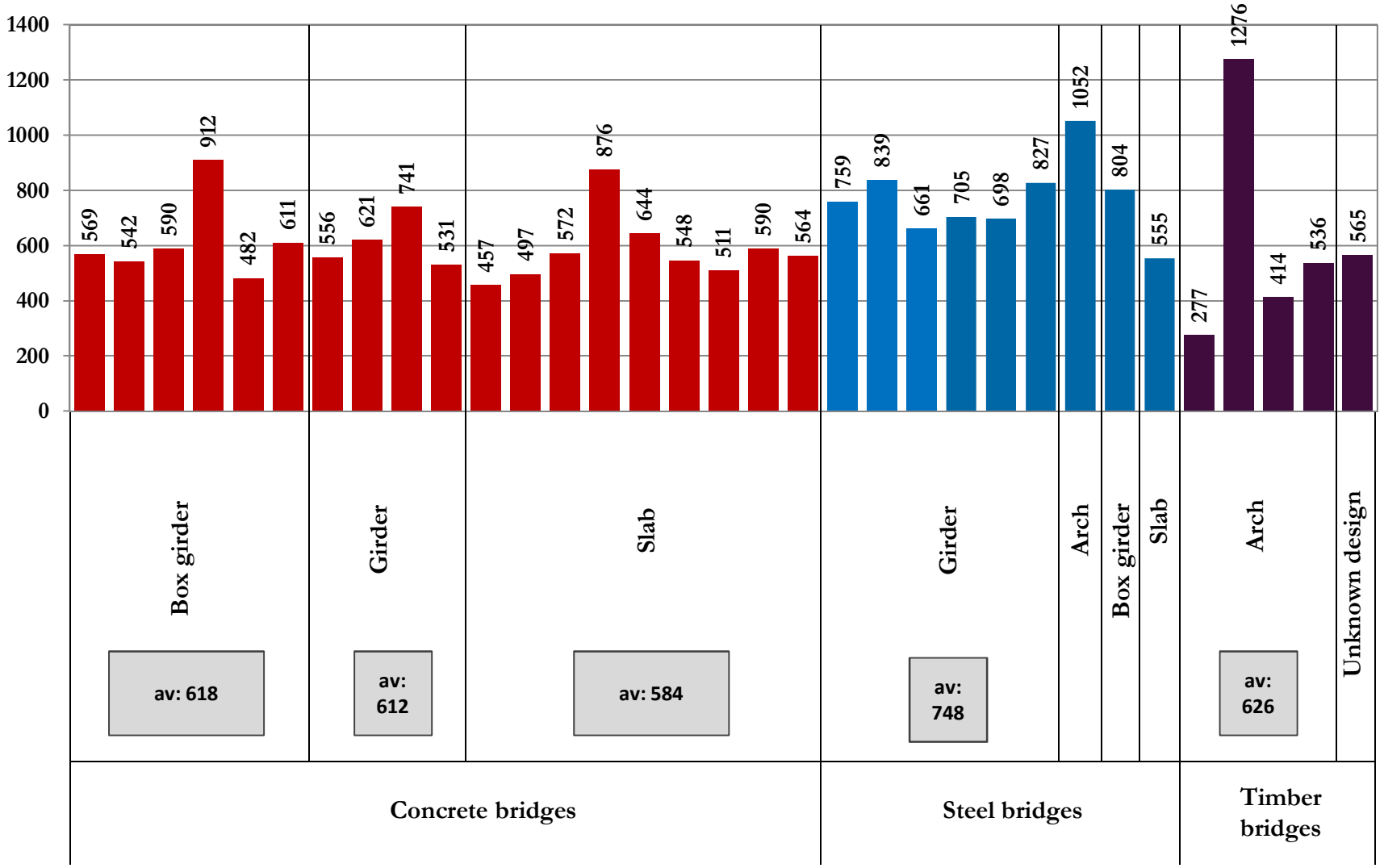
- Environmental performance of the bridges are measured by their potential impact to 5 selected environmental issues:
  - Global warming
  - Ozone depletion
  - Photochemical oxidation potential (smog)
  - Acidification
  - Eutrophication

- All results are given in emissions per m^2 effective bridge area
  - Bridge area definition: length of bridge box multiplied by bridge width (distance between the railings)
- Results in two layers
  - Total results for each category, comparison of the bridges
  - Results for global warming in more detail

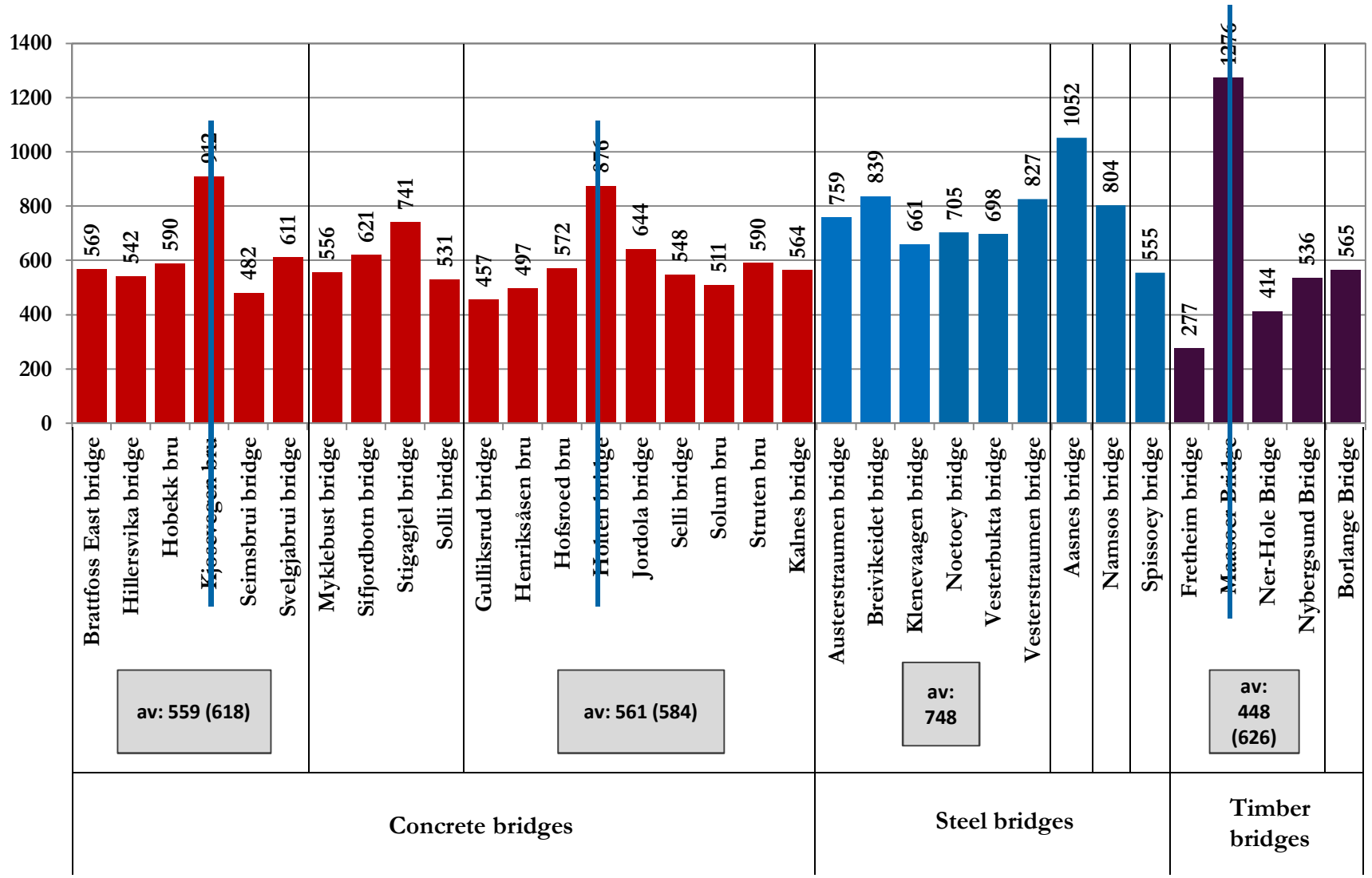
All concrete bridges - 5 Impact categories



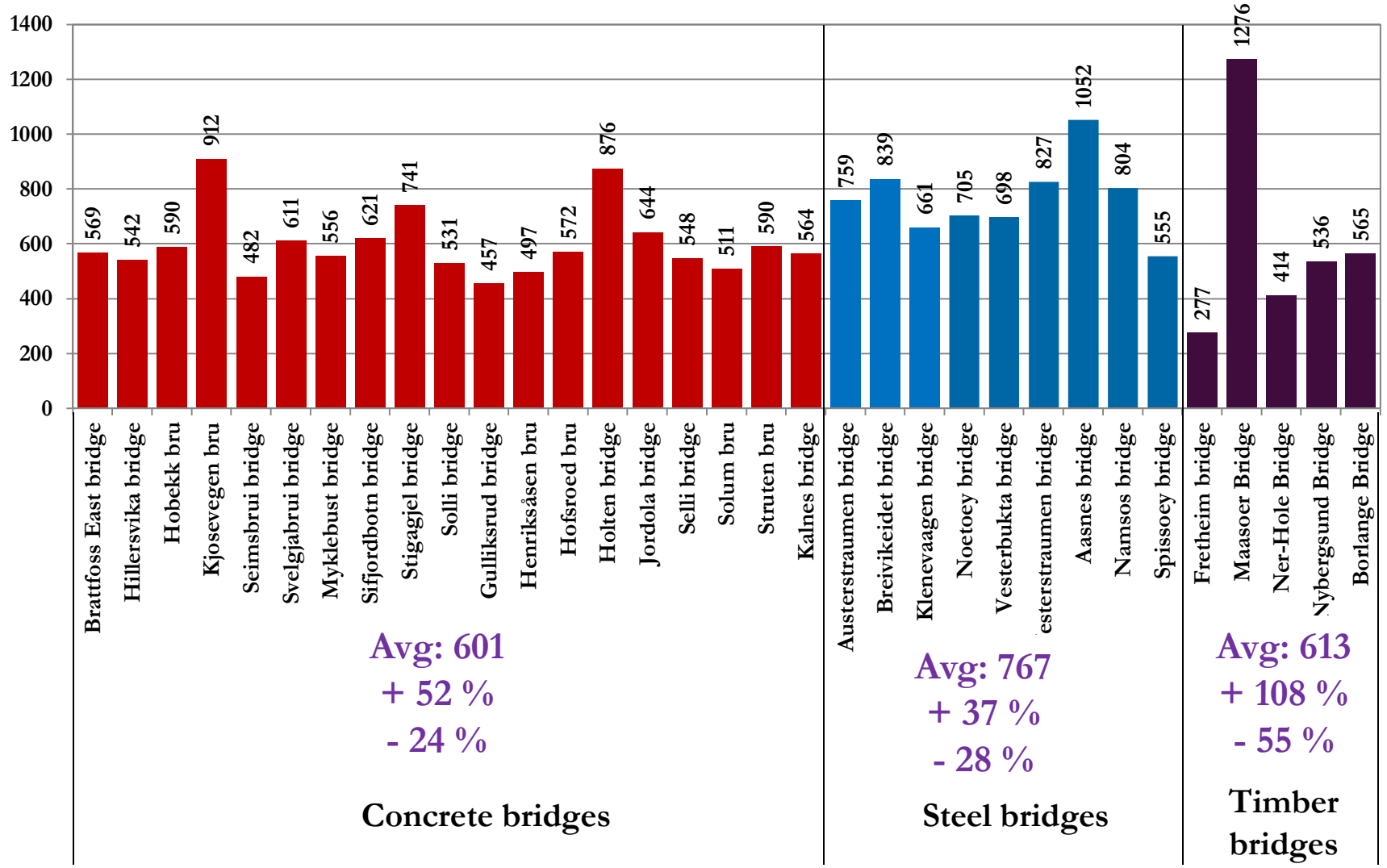
CO_2 emissions per effective surface area



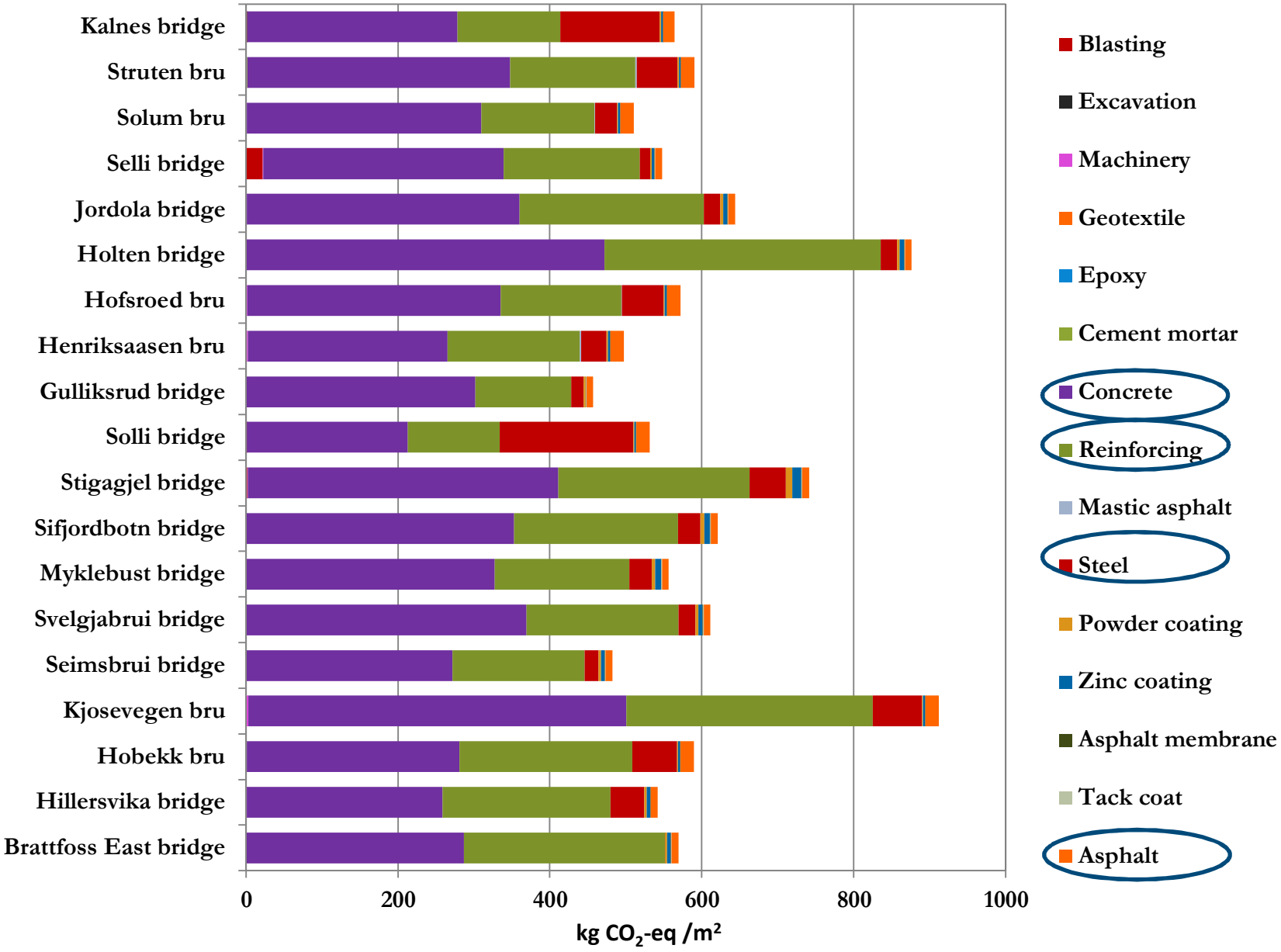
CO_2 emissions per effective surface area



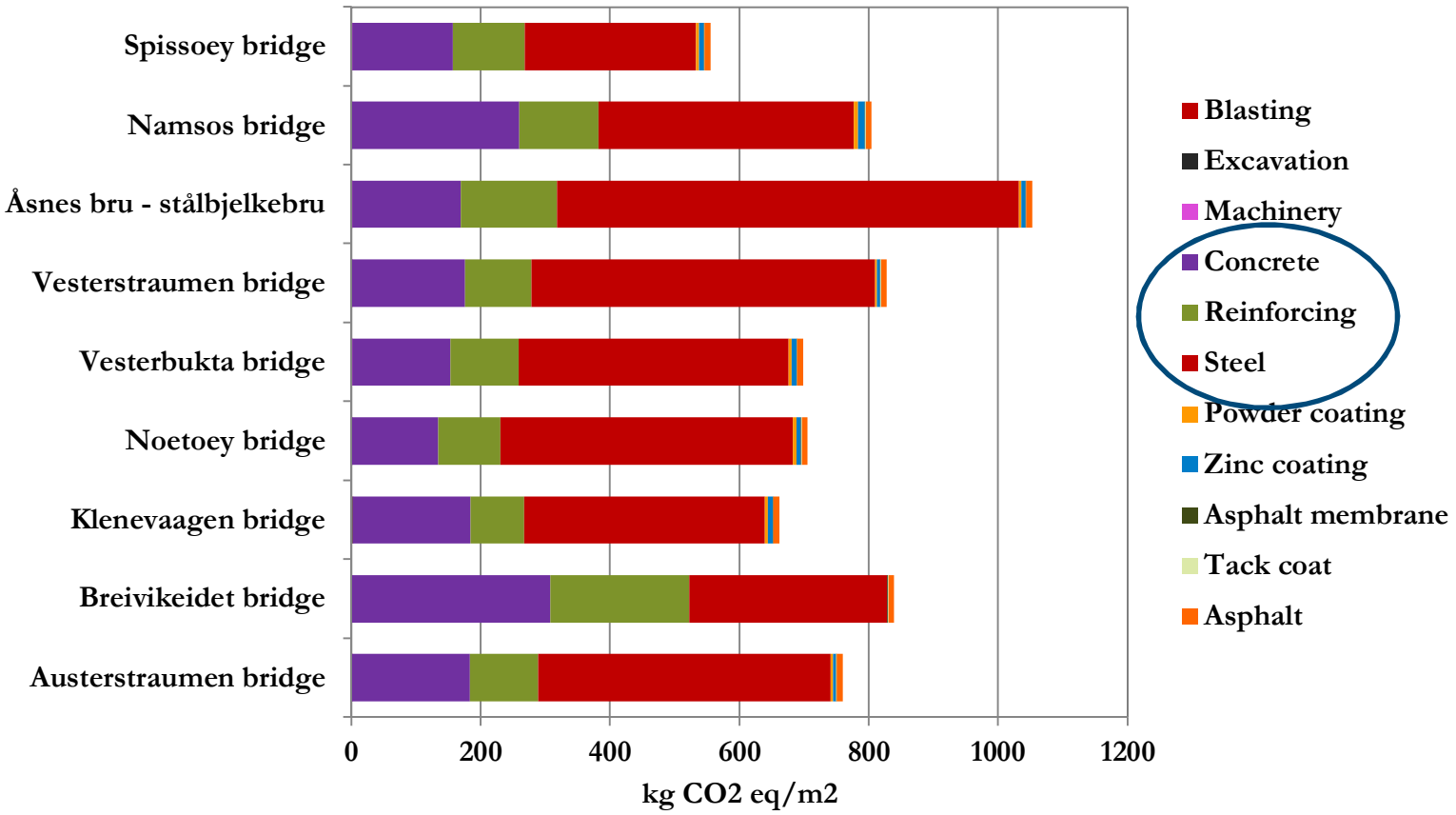
CO_2 emissions per effective surface area



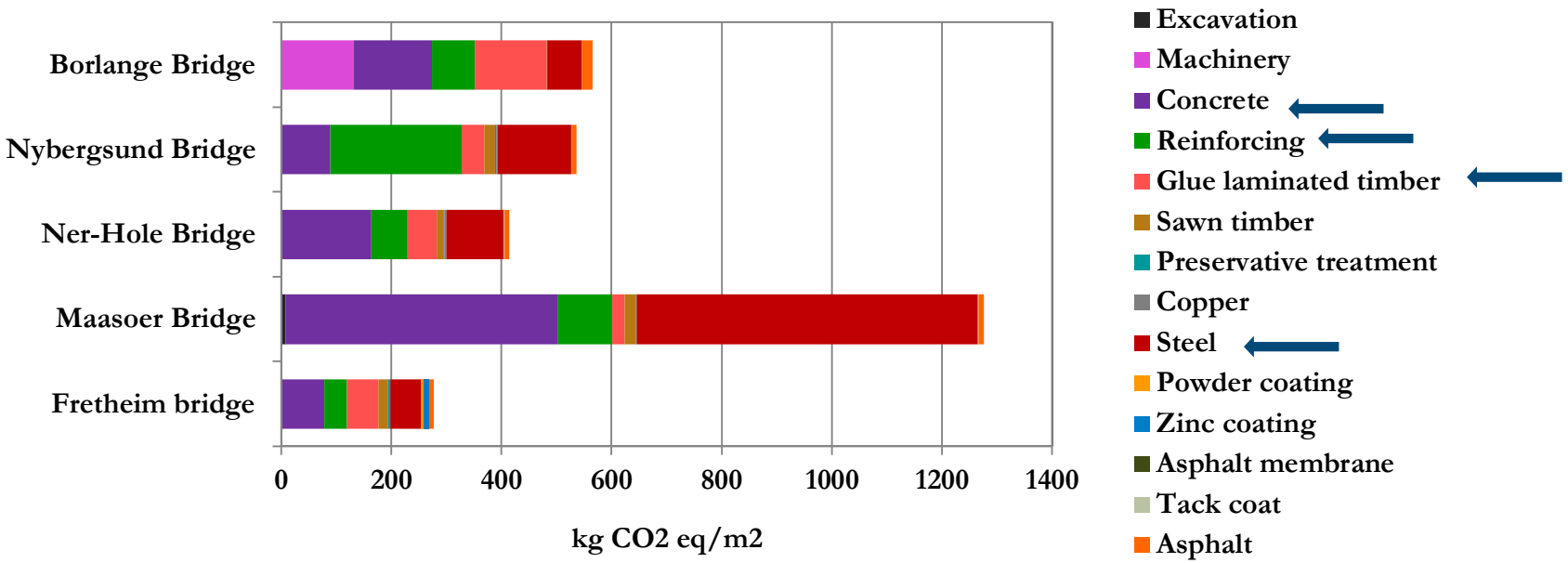
Concrete bridges – Global Warming



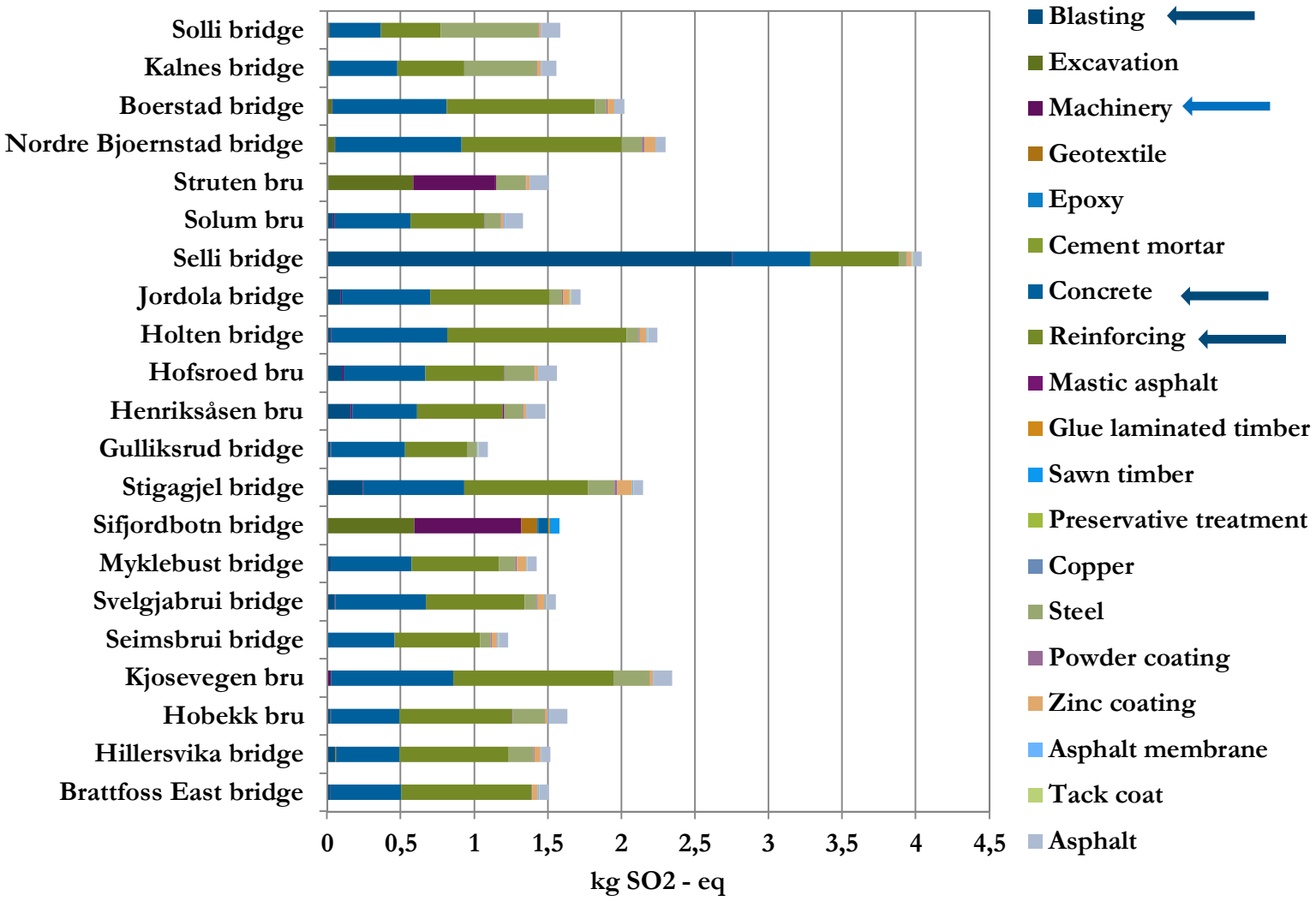
Steel bridges – Global Warming



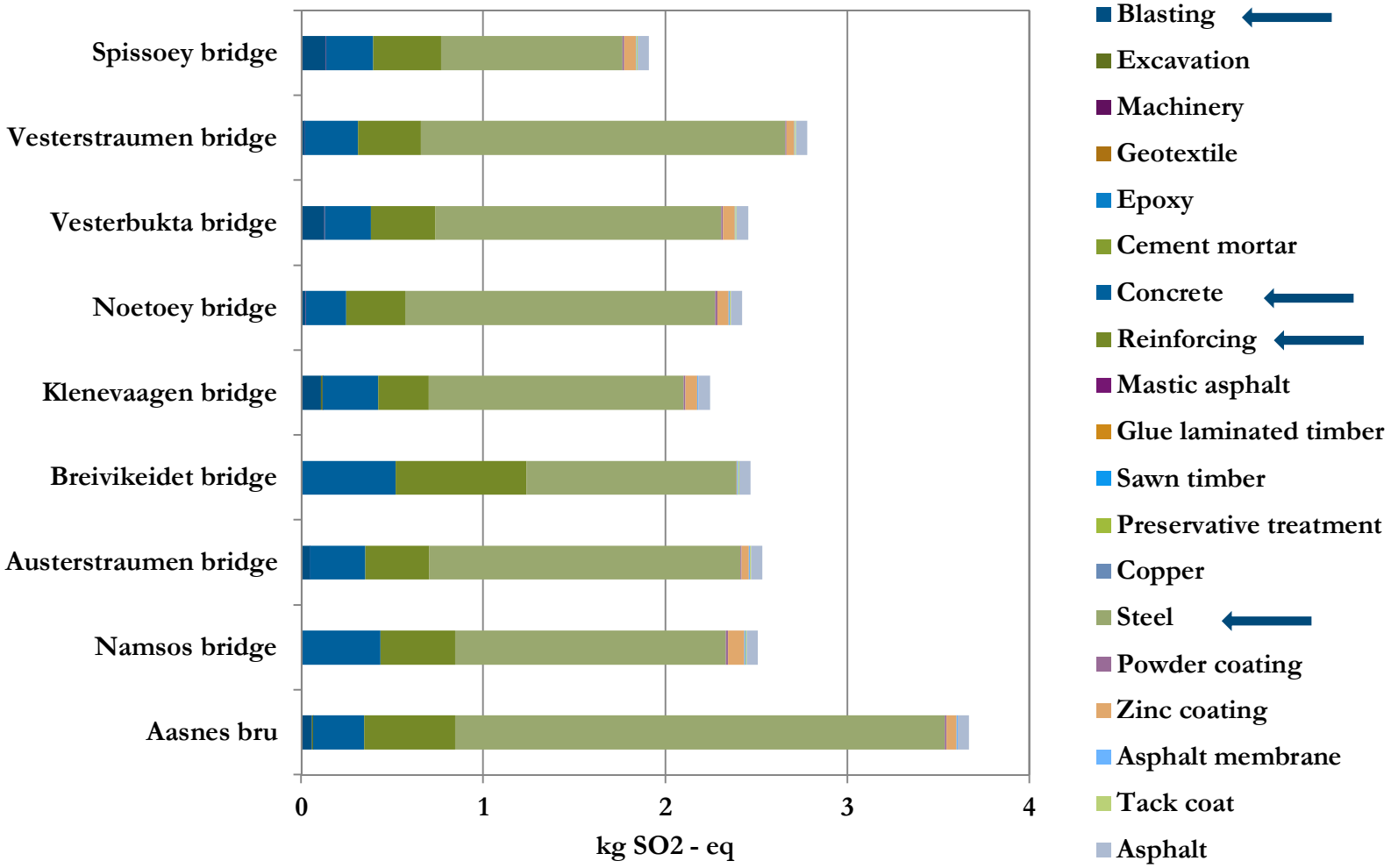
Timber bridges – Global Warming



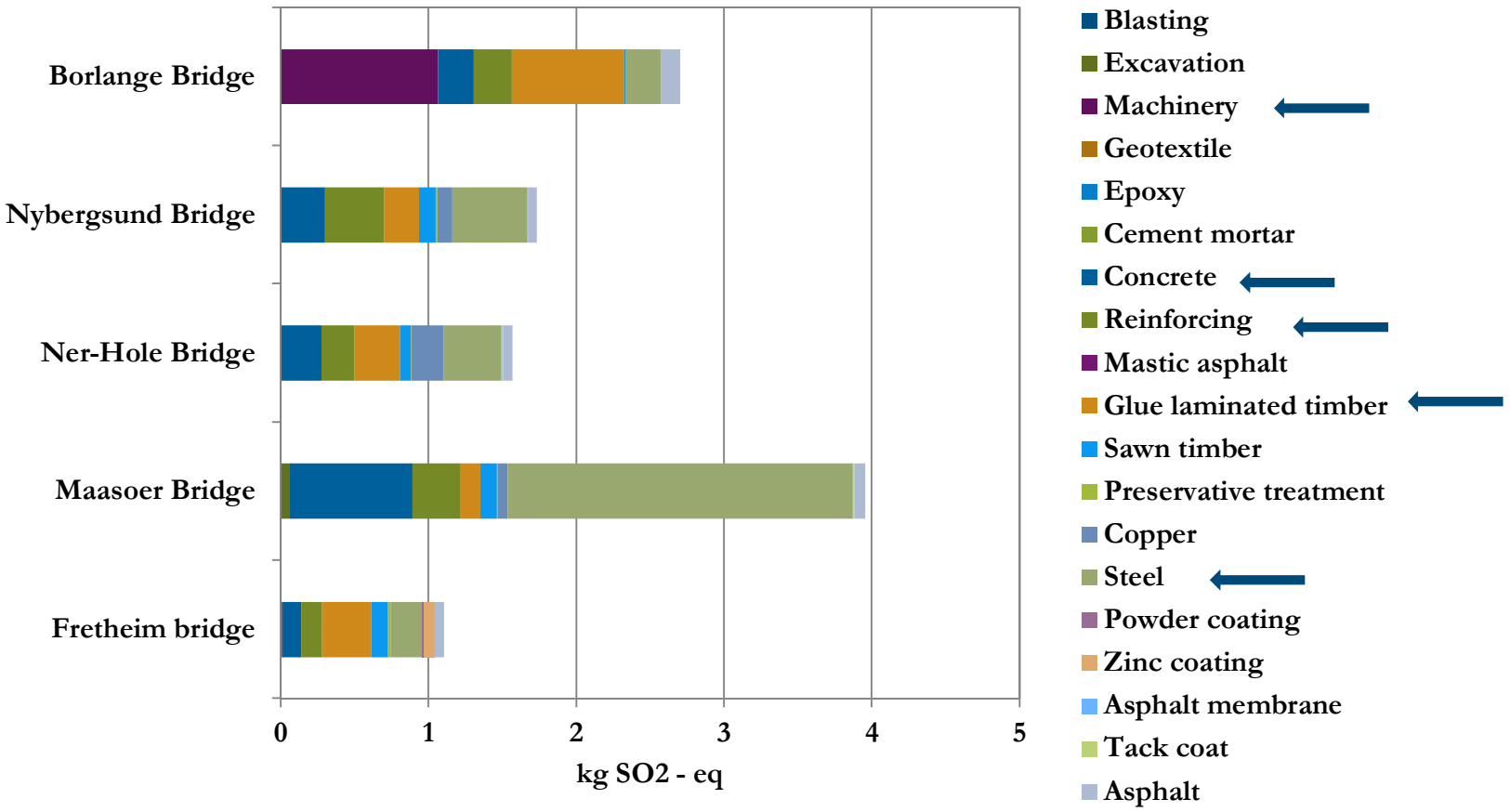
Concrete bridges – Acidification



Steel bridges – Acidification



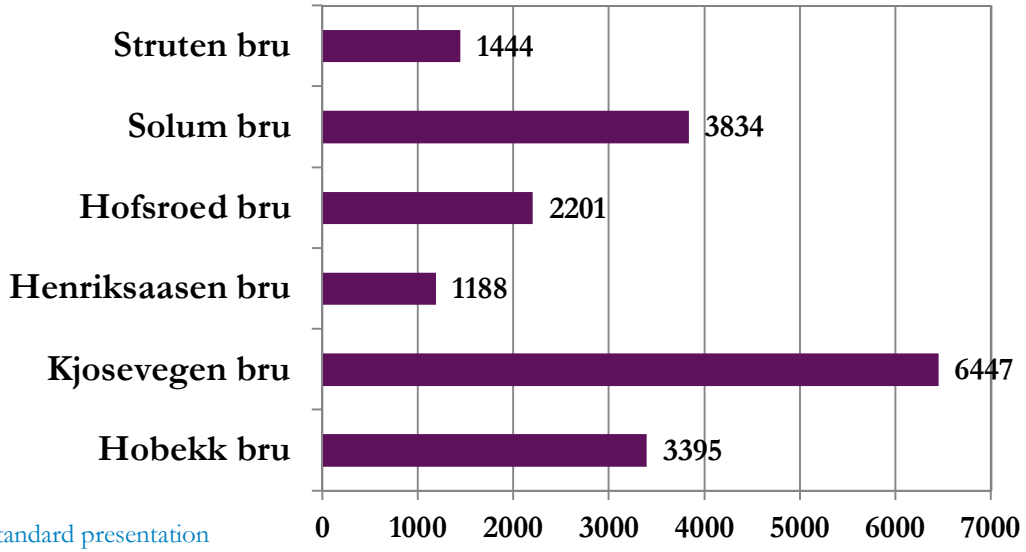
Timber bridges – Acidification



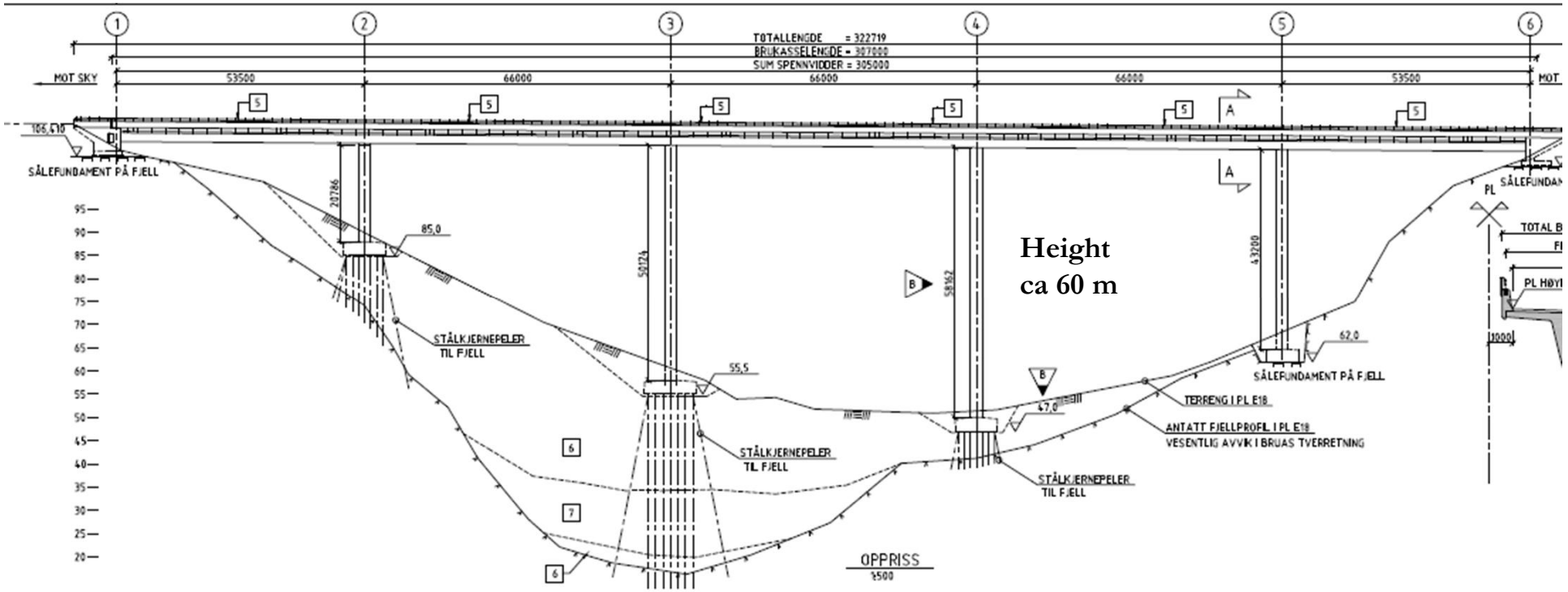
Bridges in highway project; Sky - Langangen

Bridge	Width	Length	Effective surface area	Spans	Max hight
Struten	10.5 m	67 m	1 444 m^2	2	~ 25 m
Solum	10.5 m	180 m	3 834 m^2	6	~ 25 m
Hofsroed	10.5 m	103 m	2 201 m^2	3	~ 15 m
Henriksaasen	10.5 m	55 m	1 188 m^2	3	~ 15 m
Kjosevegen	10.5 m	307 m	6 447 m^2	5	~ 60 m
Hobekk	10.5 m	160 m	3 395 m^2	3	~ 30 m

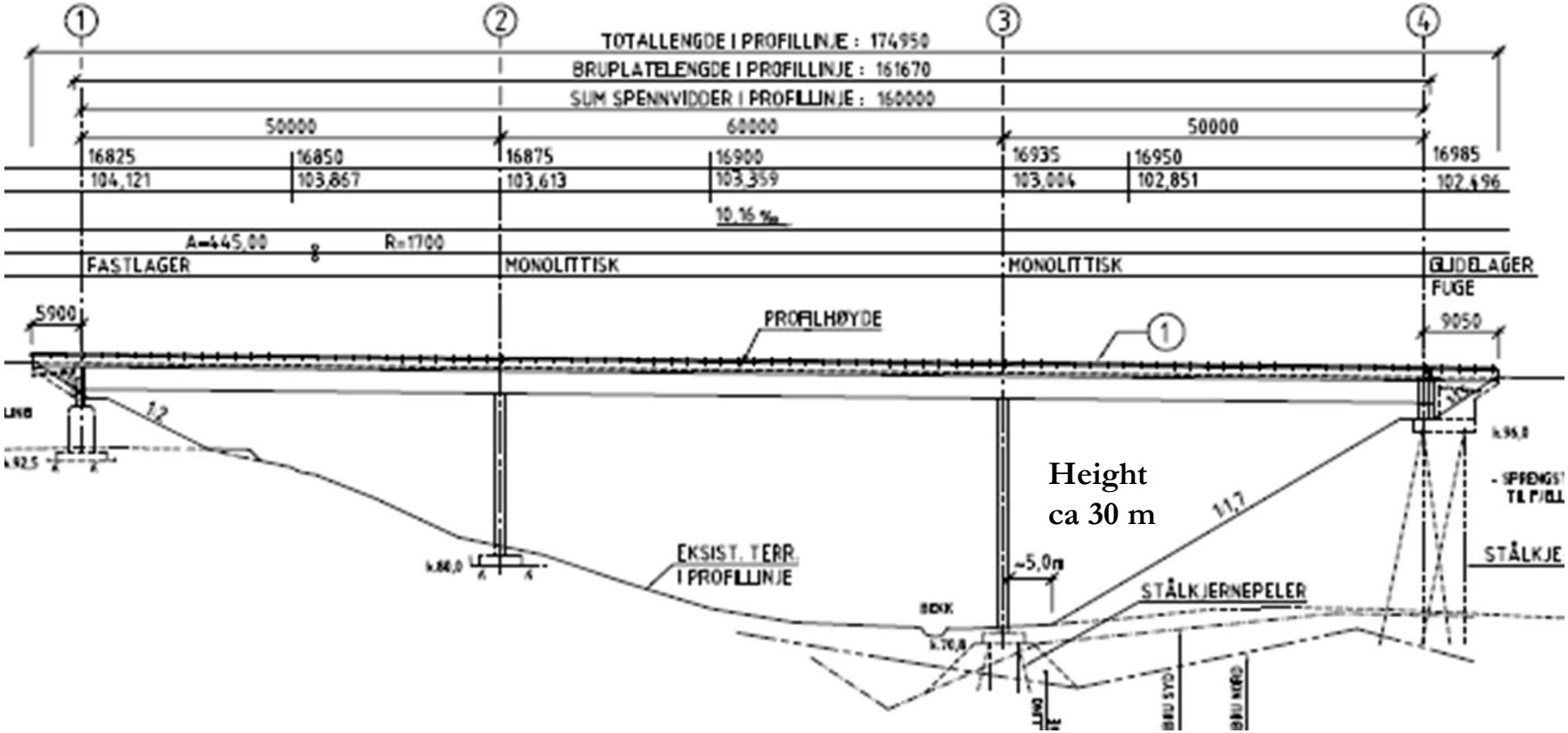
Kg CO_2-eq / m2



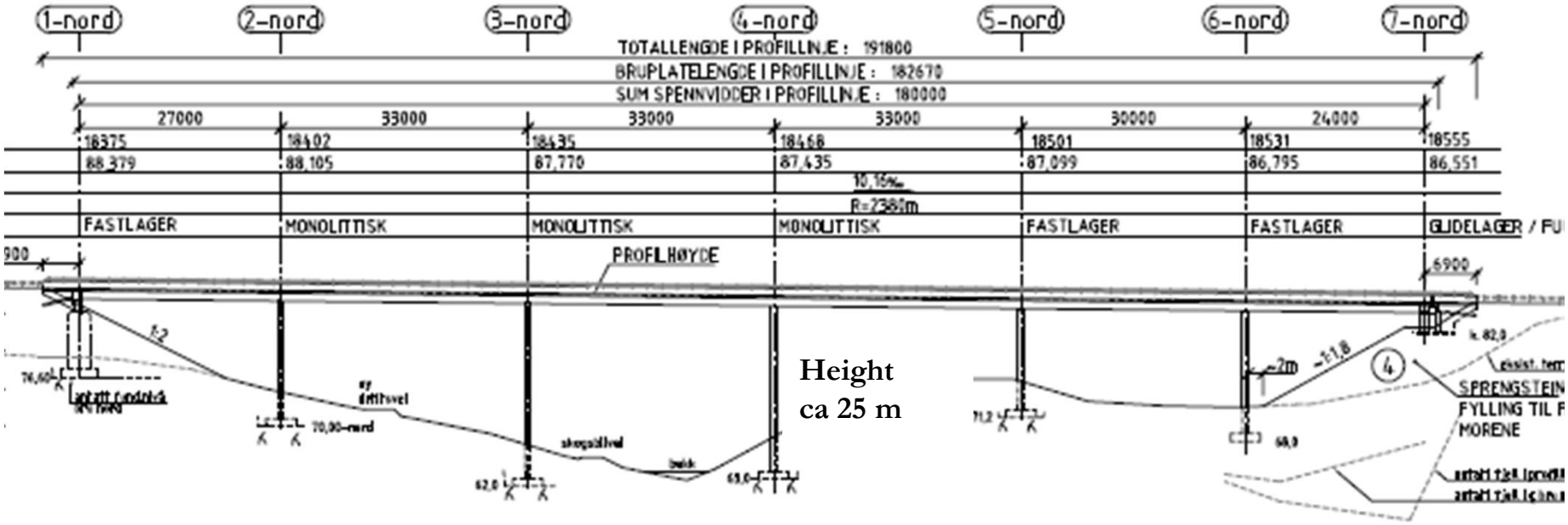
Kjosevegen bridge



Hobekk bridge

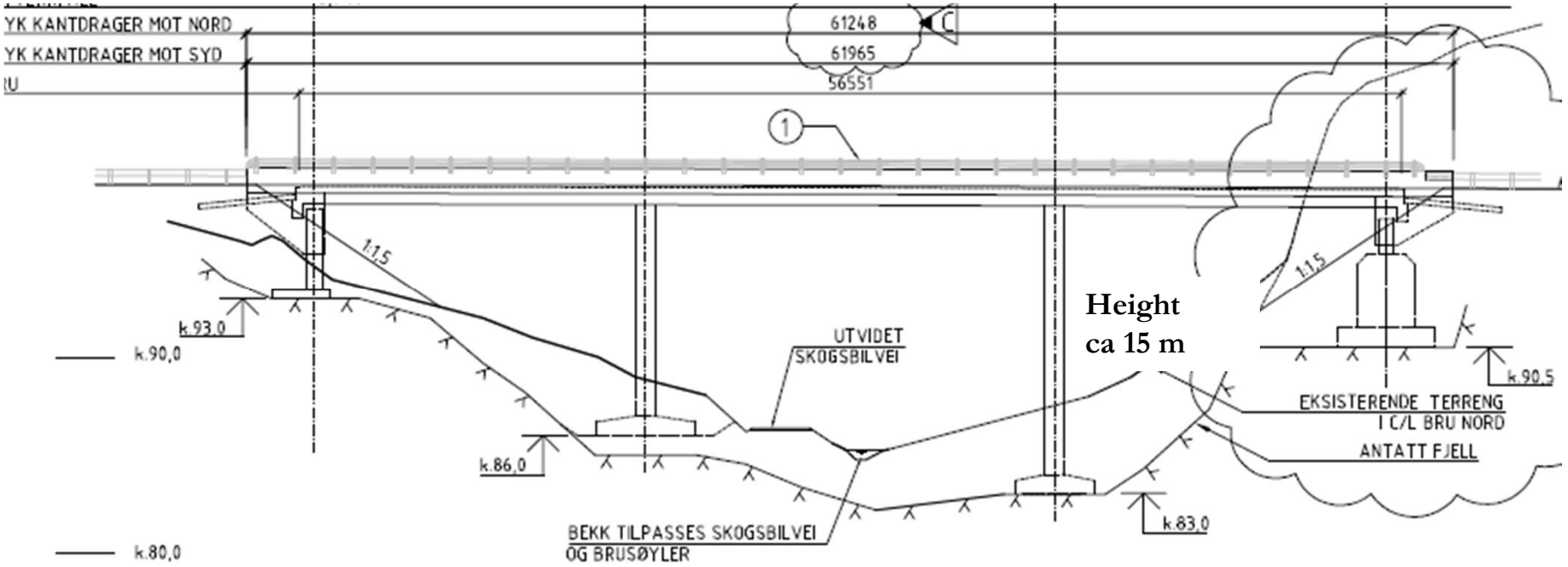


Solum bridge

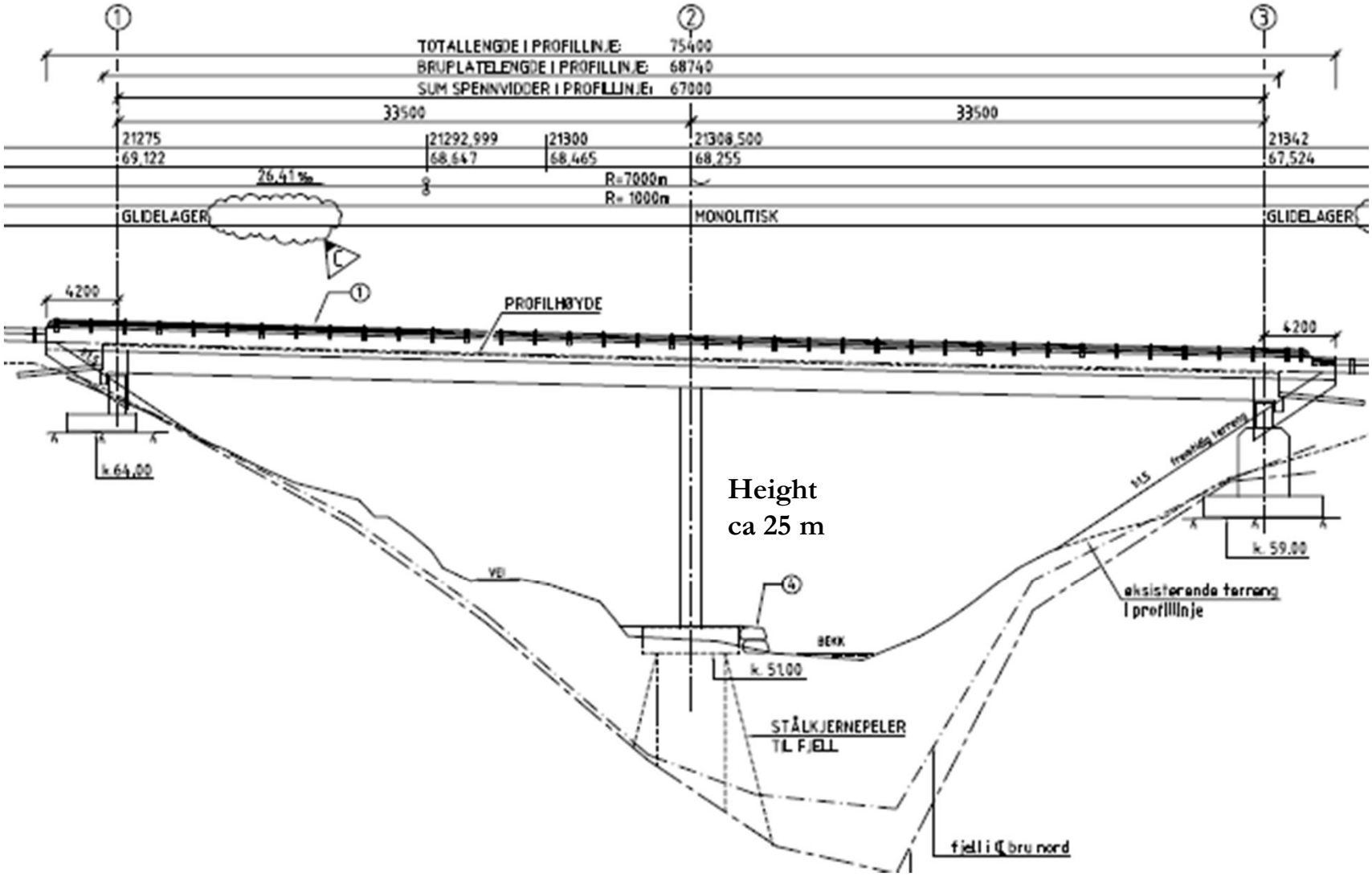


Height ca 25 m

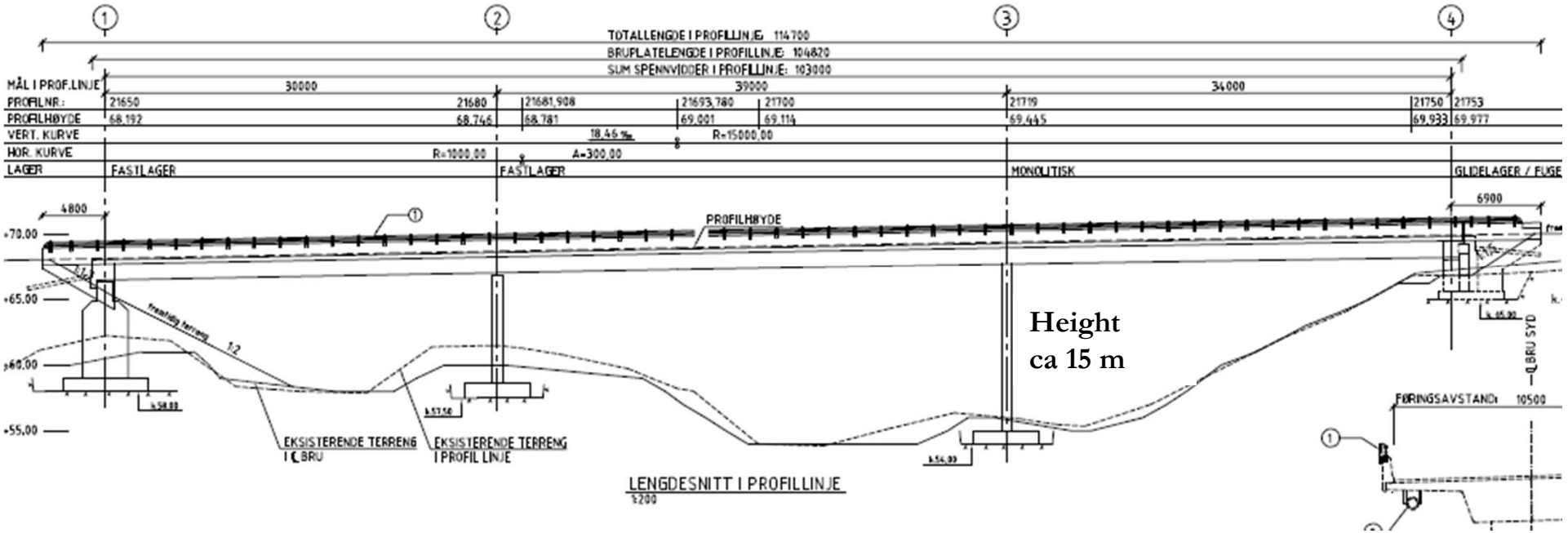
Henriksaasen bridge



Struten bridge



Hofsroed bridge



Conclusions

- Steel, concrete, reinforcing overall most important
  - Asphalt
  - Glue laminated wood
  - Machinery
  - Blasting
  - EPS (small amounts but high impact to ODP)
- Too much variations within bridge classes, and too few case bridges, to conclude on average values
  - But can say something about tendencies
- Concrete: average 601 kg CO_2-eq / m^2 (+52 %, -24 %)
- Steel: average 767 CO_2-eq / m^2 (+37 %, -28 %)
- Timber: average 613 CO_2-eq / m^2 (+108 %, -55 %)

Conclusions

- Environmental performance rankings varies for the categories
  - Trade-off necessary
- Possibilities to influence environmental performance
  - Bridge type choice
  - Design choices
  - Demands to suppliers of the most important materials

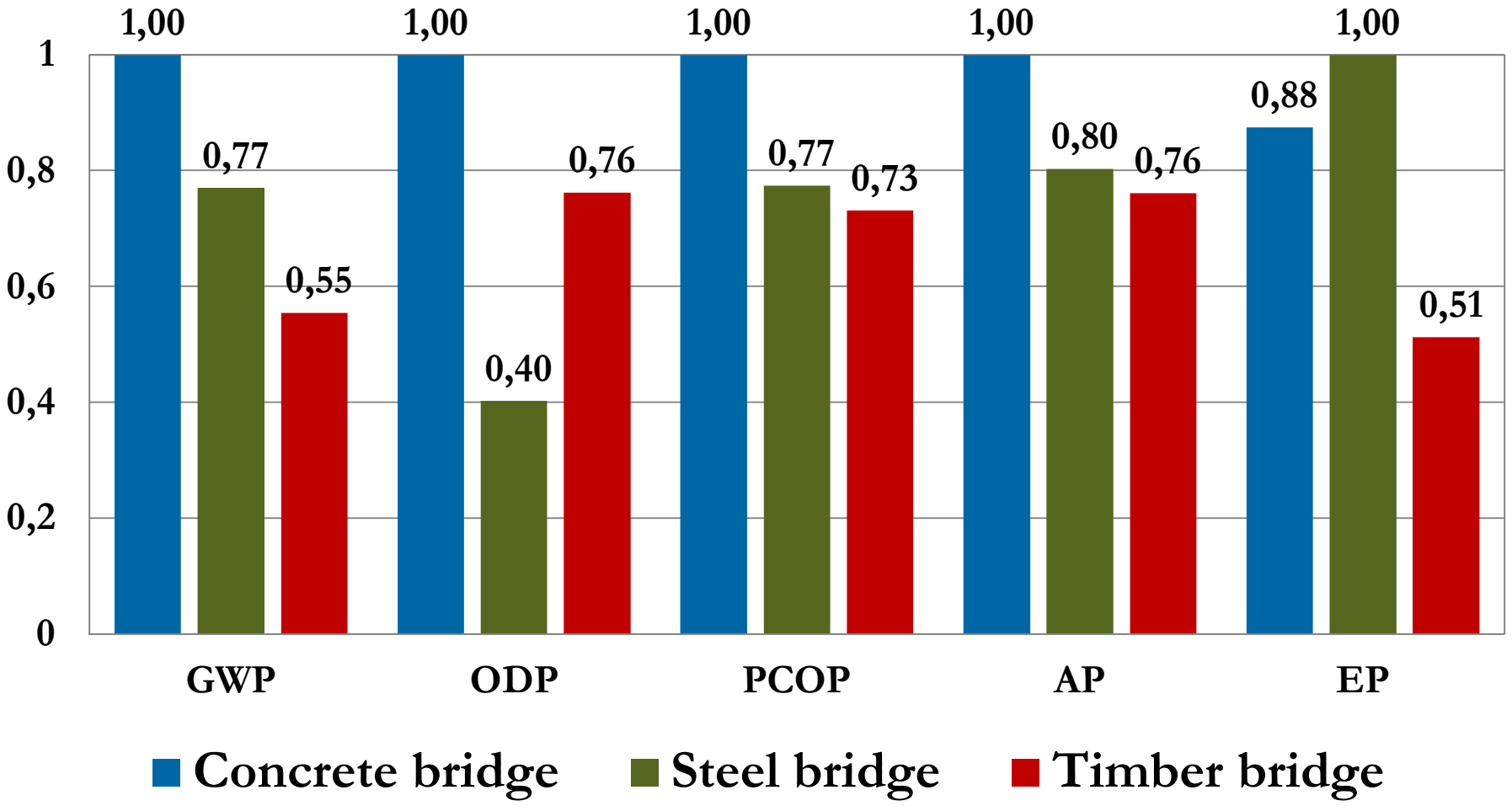
Three alternative bridge designs over Øla river

Misa study, for Reinertsen and the NPRA

- This study is part of an ongoing planning process for a new highway project in Norway
  - Bridge in study part of a side road
- Comparison of environmental performance of:
  - A concrete slab bridge
  - A steel grated bridge
  - A slab bridge of timber
- Size requirements for bridge solution:
  - Length: 65 m
  - Width: 5 m

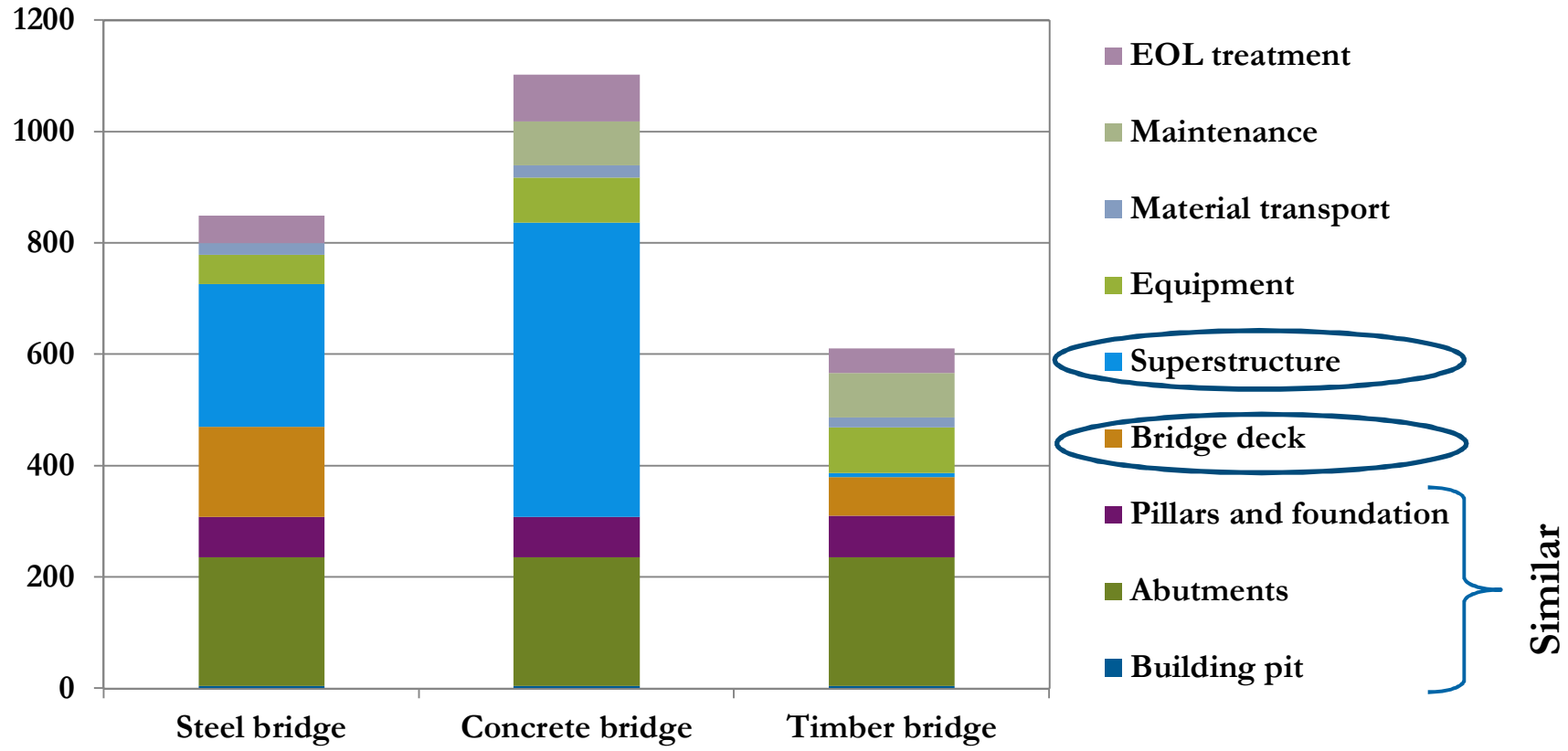
Relative results – 5 categories

Misa study, for Reinertsen and the NPRA



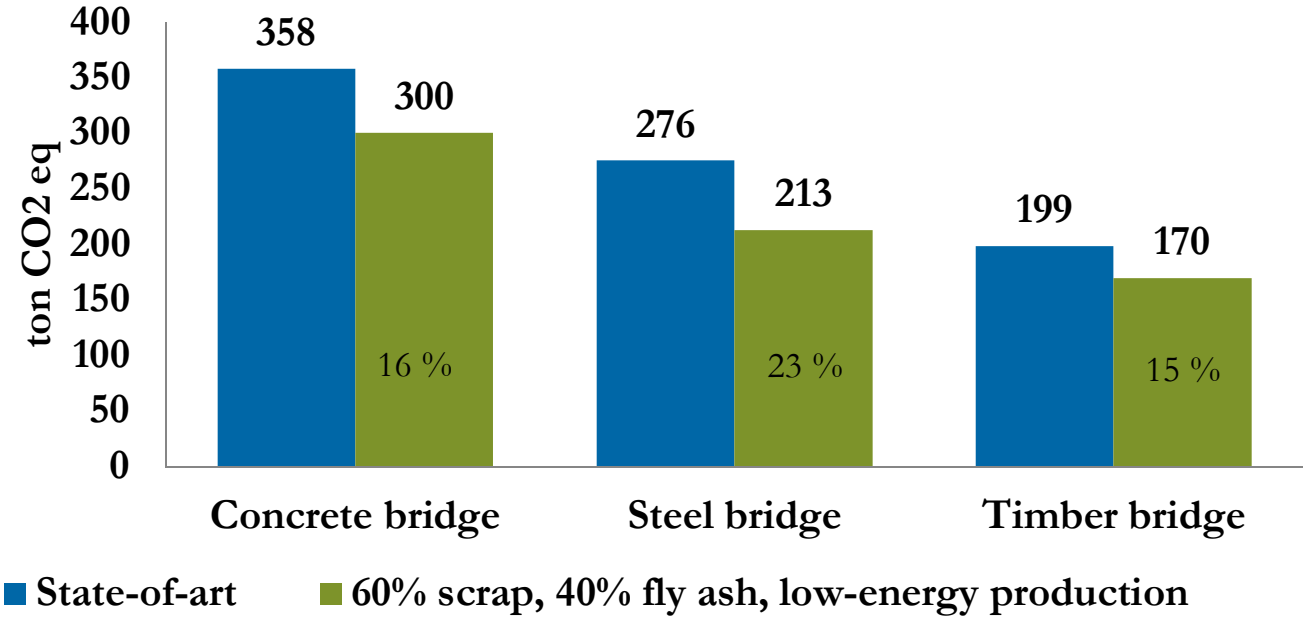
Results per m^2 effective bridge area – Global Warming

Misa study, for Reinertsen and the NPRA



Sensitivity analysis, global warming

	State-of-art	Scenario
Scrap use in steel production	37 % scrap	60 % scrap
Fly ash use in concrete production	20 % fly ash	40 % fly ash
Low-energy production	State-of-art	20 % increase in energy efficiency



Conclusions

- Timber bridge performs best
  - All categories except ozone layer depletion
- Steel bridge second
  - Exept ODP and EP
  - 4 – 49 % higher results than timber bridges
  - 23 % for GWP
- Concrete bridge
  - 14 – 45 % higher results than timber bridges
  - 45 % for GWP
- Sensitivity
  - 15 – 23 % improvement (GWP)

Conclusions

- Improvement of environmental performance
  - Choice of bridge type
  - Demands to material supplier or choice of supplier
- Freedom of choice?
  - Requirement to bridge design related to
    - Traffic
    - Bridge site
    - economics
    - Aestetics

misa

miljøsystemanalyse
environmental systems analysis

a systems perspective to environmental research and consulting

www.misa.no