Recycle, Bury or Burn Clean Wood Waste?

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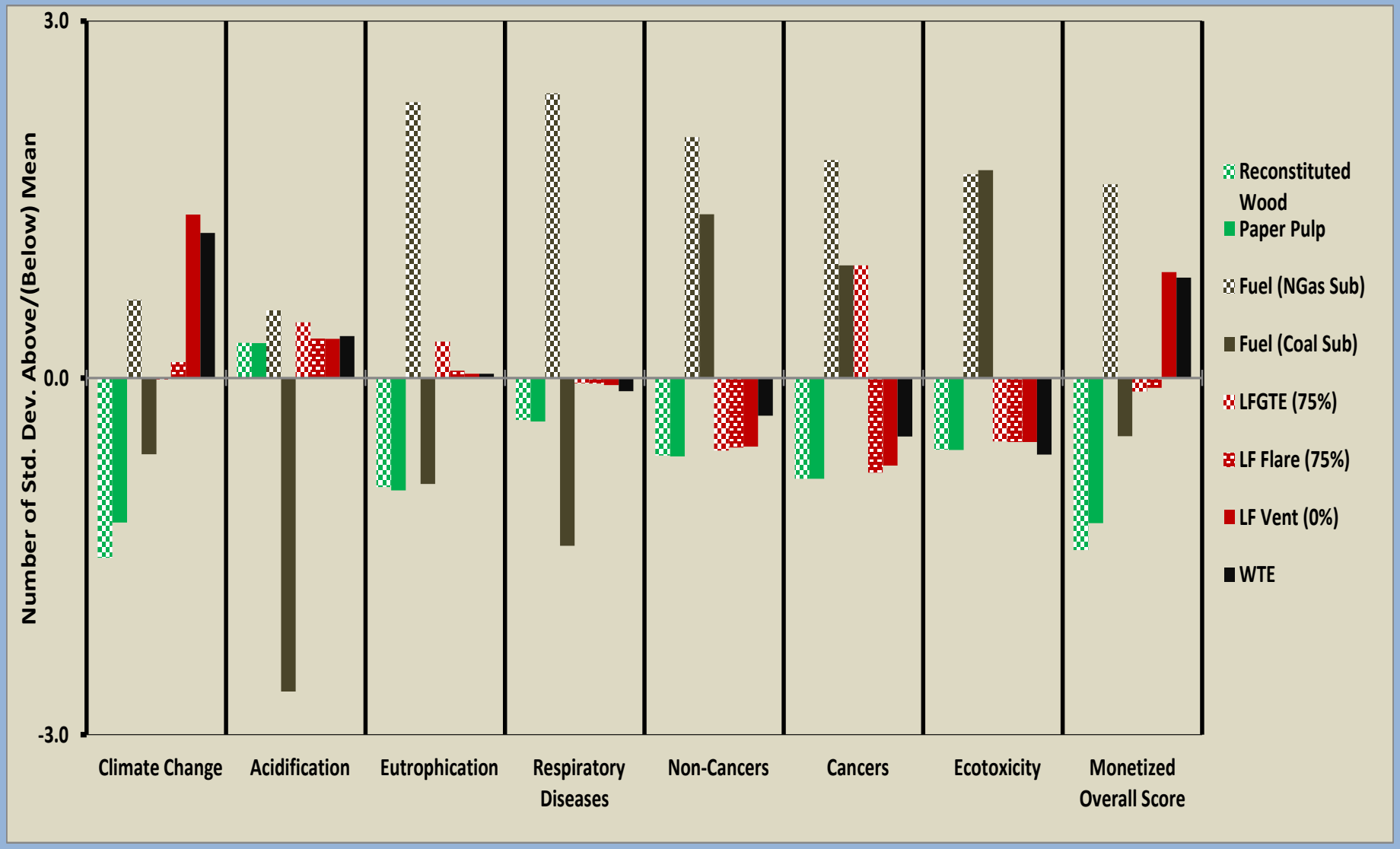
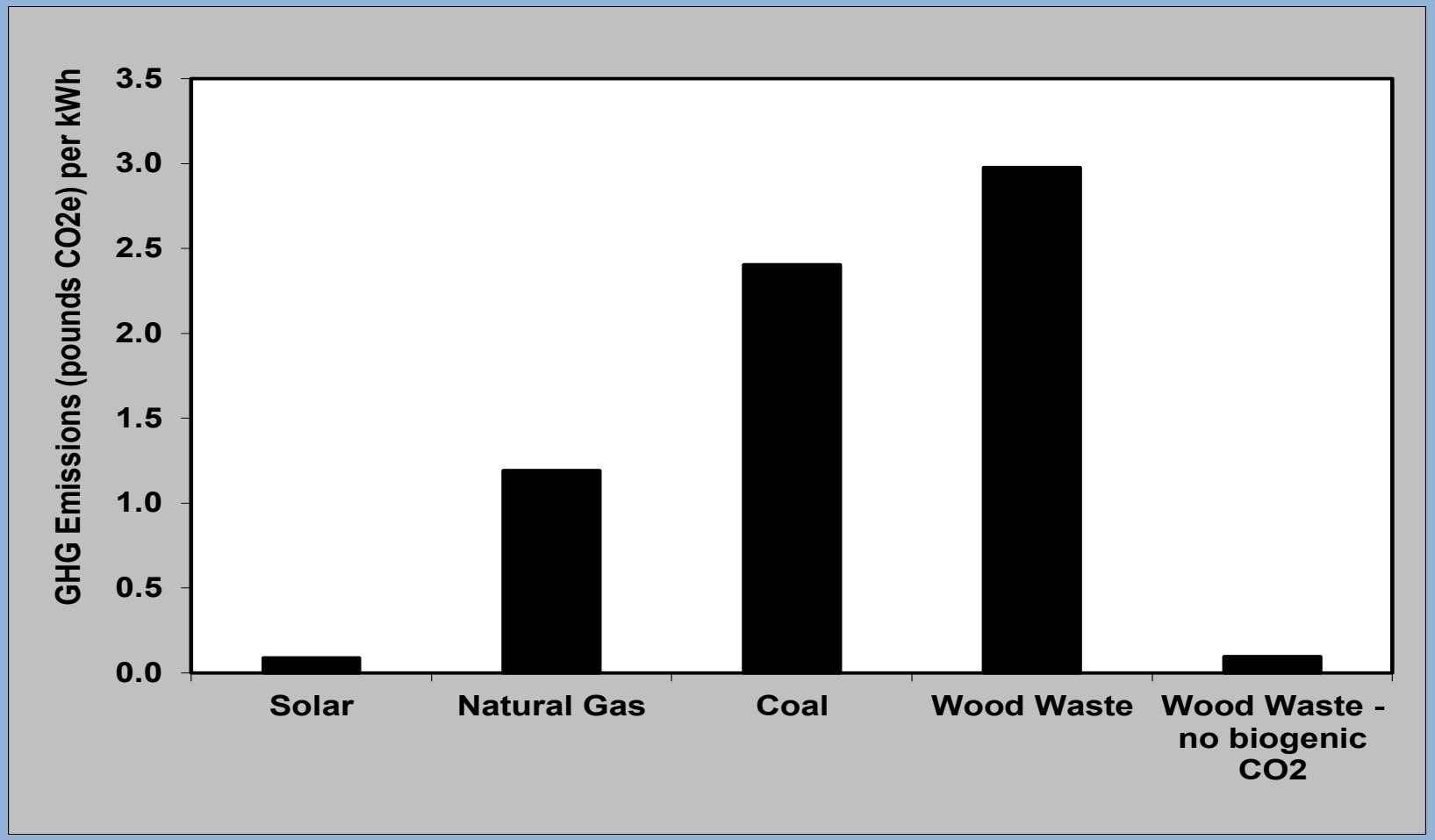
Life Cycle Impacts for Clean Wood
Current Best Carbon Accounting Methodology



Clean Wood Waste Management Methods
Carbon Emissions & Emissions Offsets
(kg eCO_2 per metric ton wood)

Base Case	Wood Pro-Ducts	Paper Pulp	Fuel vs. N. Gas	Fuel vs. Coal	LFGTE (75%)	Flare LFG (75%)	Vent LFG	WTE
Direct Emissions								
Hauling	18	18	4	4	5	5	5	2
Processing & Chipping	92	92	69	69				
Combustion			1,559	1,559	155	151		1,528
Biodegradation					288	288	1,152	
Disposal Operations			1	1	19	19	19	32
Emissions Offsets								
Tree Harvest Slash	(537)	(376)						
Reconstituted Wood Production Inputs	(56)							
Pulping Wood Production Inputs		(47)						
Natural Gas Production & Combustion			(868)		(88)			(475)
Coal Production & Combustion				(1,616)				
Net Emissions	(483)	(313)	765	17	379	463	1,176	1,087
Ranking (best = 1)	1	2	6	3	4	5	8	7

Carbon Footprints for Electricity Generation



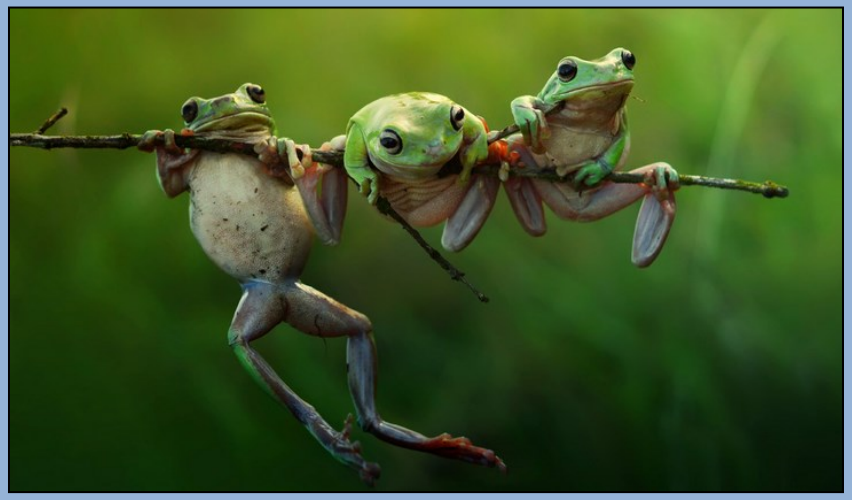
Sources: Kim, H. C.; Fthenakis, V.; Choi J-K.; Turney, D. E., 2012. Life Cycle Greenhouse Gas Emissions of Thin-film Photovoltaic Electricity Generation – Systematic Review and Harmonization. *Journal of Industrial Ecology* 16 (S1): S110-S121; Morris, J., 2010. Bury or burn North American MSW? LCAs provide answers for climate impacts & carbon neutral power potential. *Environmental Science & Technology* 44 (20): 7944-7949; Morris, J., 2014. Recycle, Bury, or Burn Wood Waste Biomass? – LCA Answer Depends on Carbon Accounting, Emissions Controls, Displaced Fuels & Impact Costs. *Journal of Industrial Ecology*, in peer review; and Whitaker, M. B.; Heath, G. A.; Burkhardt, III, J. J.; Turchi, C. S., 2013. Life Cycle Assessment of a Power Tower Concentrating Solar Plant and the Impacts of Key Design Alternatives. *Environmental Science & Technology* 47 ( ): 5896-5903.

Carbon Footprint Accounting Issues

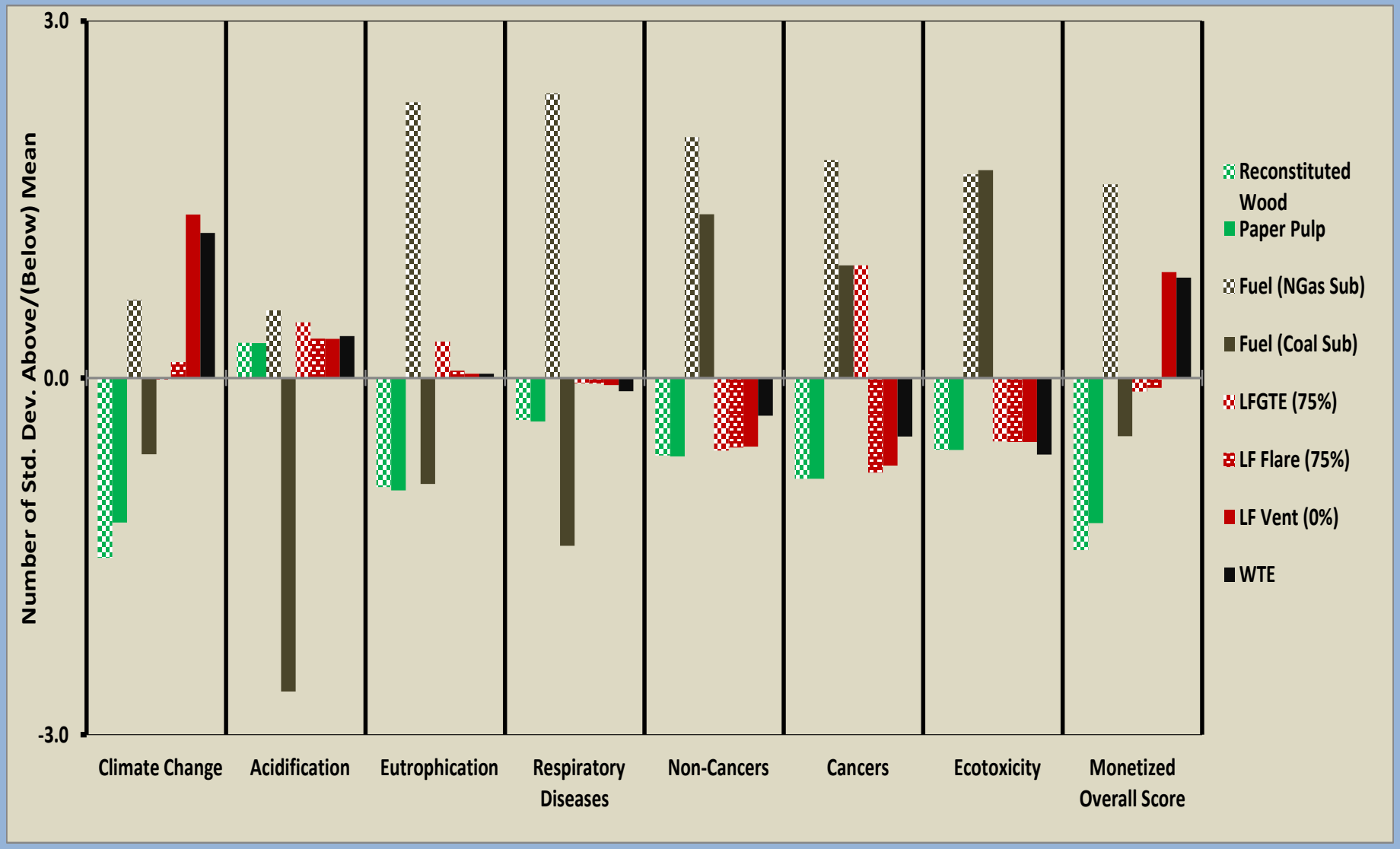
- **Count Biogenic Carbon Dioxide (CO_2) Emissions?**
- **Account for emissions timing?**
- **Account for carbon storage?**
- **Indexing non-CO_2 emissions into CO_2 equivalents**

General Environmental Footprinting Issues

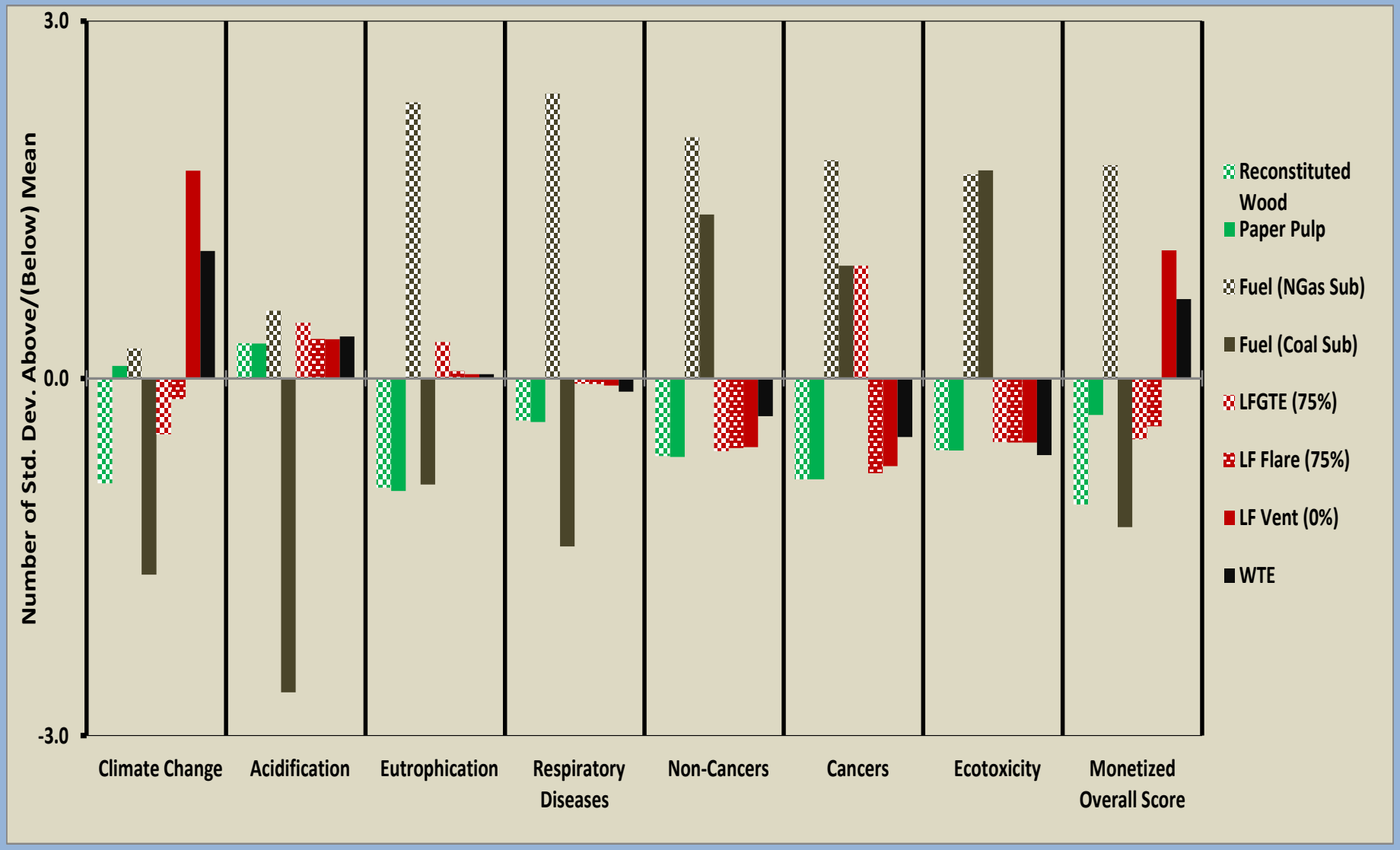
- Indexing environmental impacts from pollution
- Pollution location, timing & persistence
- Upstream pollution (e.g., vs. stack emissions)
- Determining which impacts matter most
- Obtaining robust emissions profiles



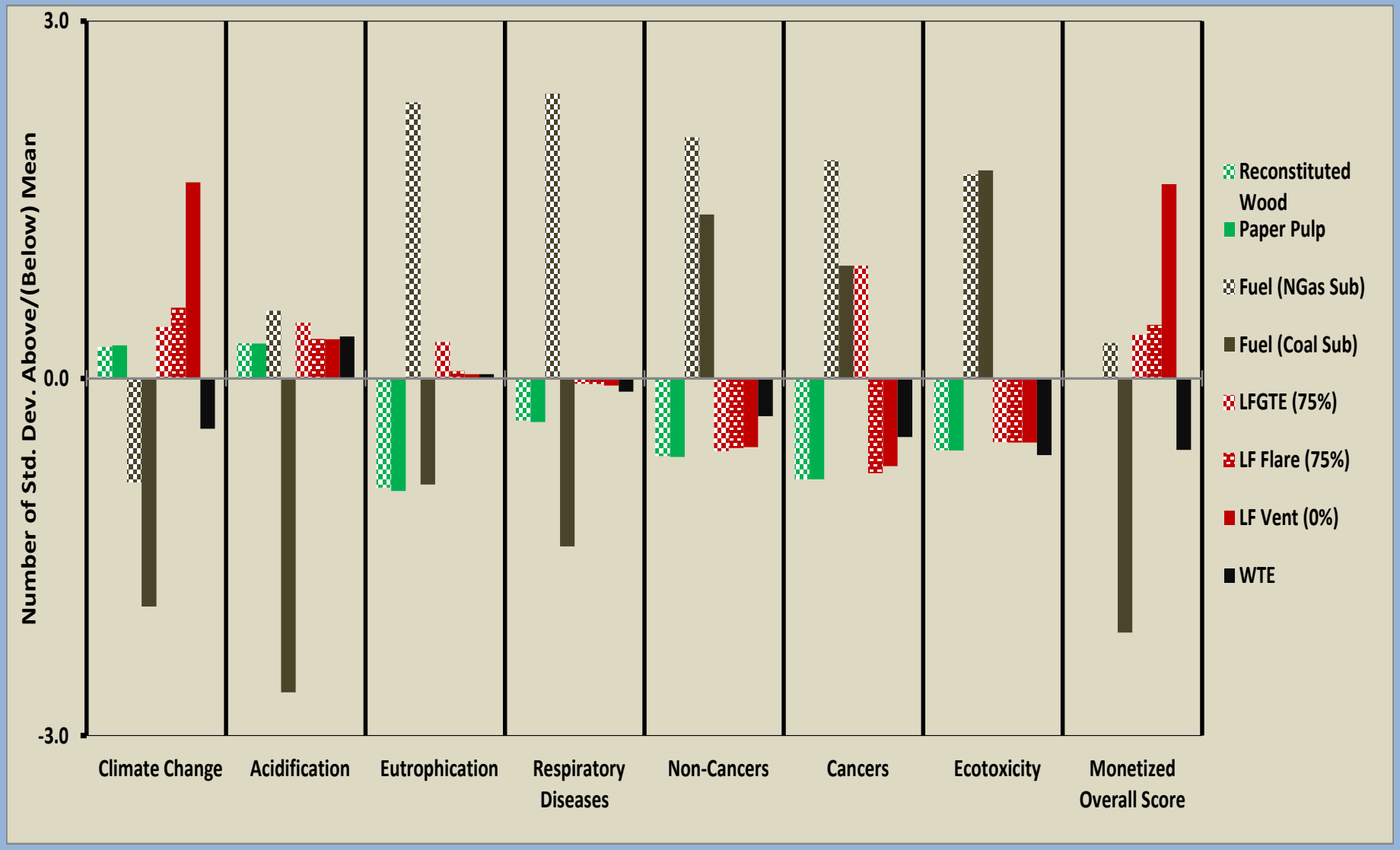
Life Cycle Impacts for Clean Wood
Current Best Carbon Accounting Methodology



Life Cycle Impacts for Clean Wood
No Discounting for GHG Timing, No BioCO_2



Life Cycle Impacts for Clean Wood
No Discounting, No BioCO_2, No Carbon Storage



Sensitivity to Boiler Emissions Controls

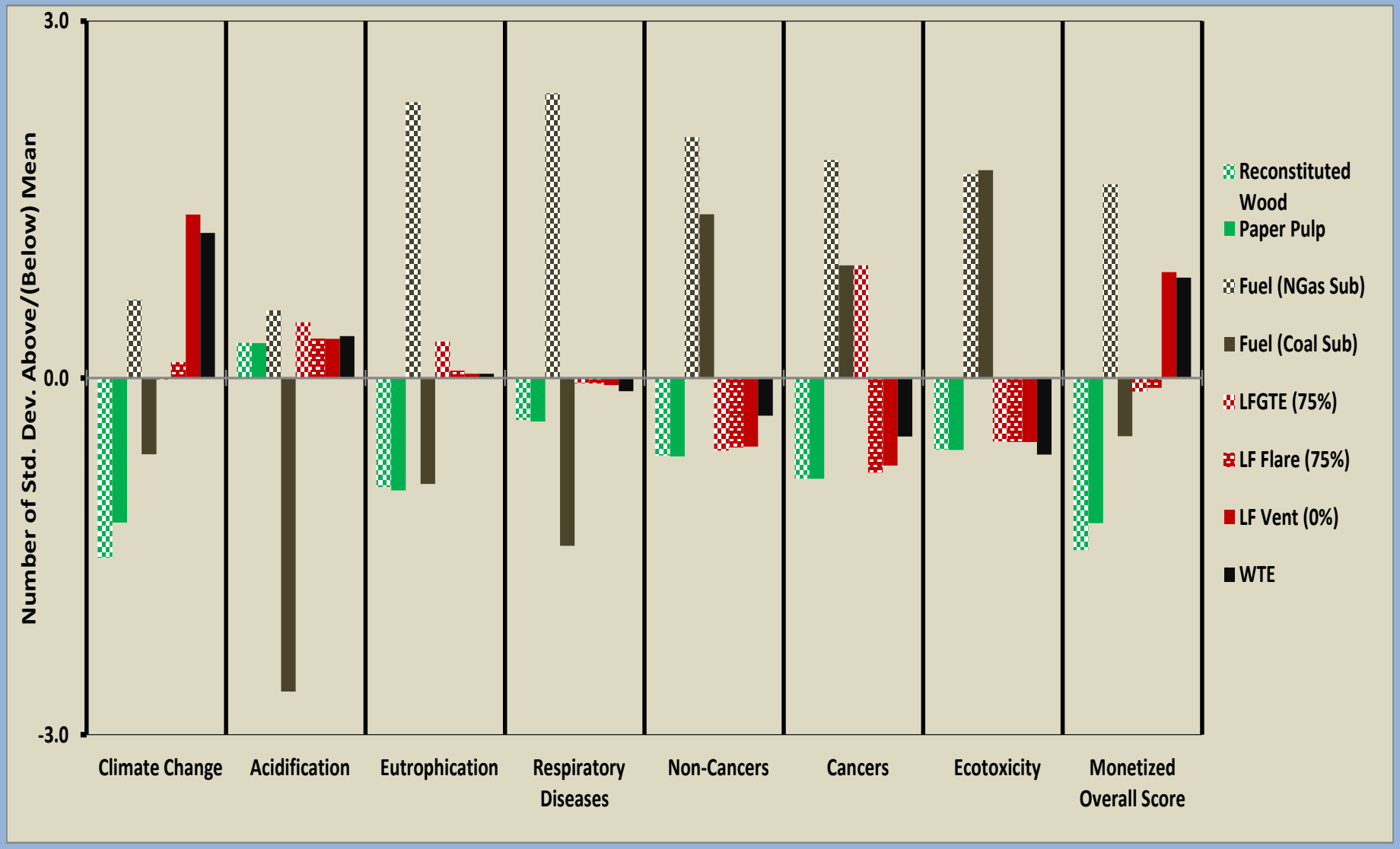
Base Case Industrial Boiler Controls (AP-42 estimates)

- Wood – mechanical collector (e.g., cyclone), dry wood
- Natural Gas – none, large boiler
- Coal – ESP, 2.35% sulfur bituminous coal

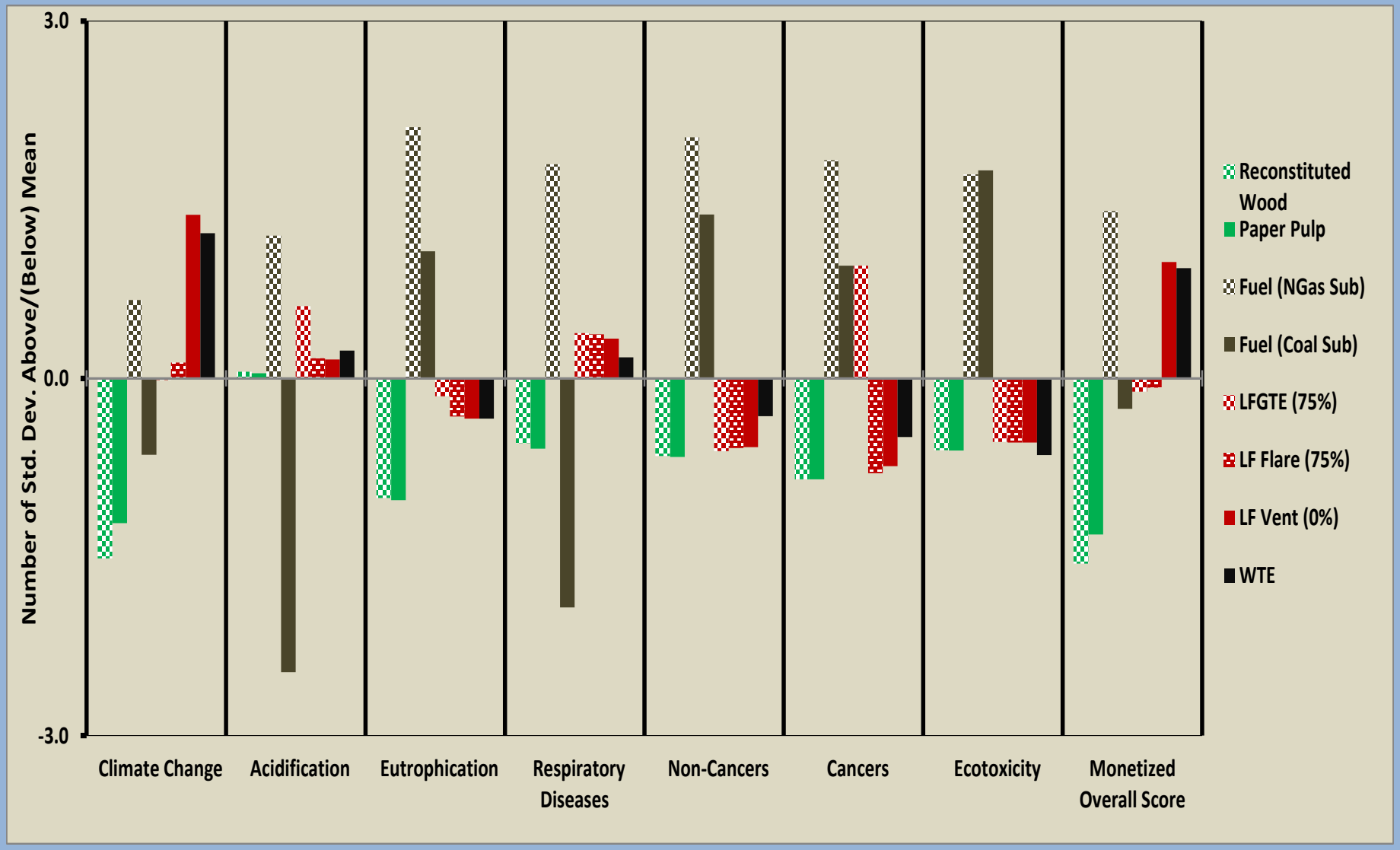
Industrial Boiler Controls for Low Emissions (AP-42 estimates)

- Wood – ESP, wet wood (>20% moisture)
- Natural Gas – low NOx small boiler, flue gas recirculation
- Coal – baghouse, 1% sulfur bituminous coal, flue gas desulfurization

Life Cycle Impacts for Clean Wood
Current Best Carbon Accounting Methodology



Life Cycle Impacts for Clean Wood
Best C Acct. + Better Boiler Emissions Controls



Clean Wood Waste Management Methods
Carbon Emissions & Emissions Offsets
(kg eCO_2 per metric ton wood)

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Processing & Chipping	92	92	69	69				
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Disposal Operations			1	1	19	19	19	32
Emissions Offsets								
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Ranking (best = 1)	1	2	6	3	4	5	8	7

Clean Wood Waste Management Methods
No Discounting, No Biogenic CO_2 Counted
(kg eCO_2 per metric ton wood)

Base Case	Wood Pro-Ducts	Paper Pulp	Fuel vs. N. Gas	Fuel vs. Coal	LFGTE (75%)	Flare LFG (75%)	Vent LFG	WTE
Direct Emissions								
Hauling	18	18	4	4	5	5	5	2
Processing & Chipping	92	92	69	69				
Combustion			32	32	16	11		1
Biodegradation					255	255	1,021	
Disposal Operations			1	1	19	19	19	32
Emissions Offsets								
Reconstituted Wood Production Inputs	(56)							
Pulping Wood Production Inputs		(47)						
Natural Gas Production & Combustion			(868)		(121)			(475)
Coal Production & Combustion				(1,616)				
Temporary Carbon Storage	(1,262)	(883)			(1,220)	(1,220)	(1,220)	
Net Emissions	(1,208)	(820)	(762)	(1,510)	(1,046)	(930)	(175)	(440)
Ranking (best = 1)	2	5	6	1	3	4	8	7

Thank you.

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