Life Cycle Assessment (LCA): More Than Just Trucks, MRFs & Climate Change

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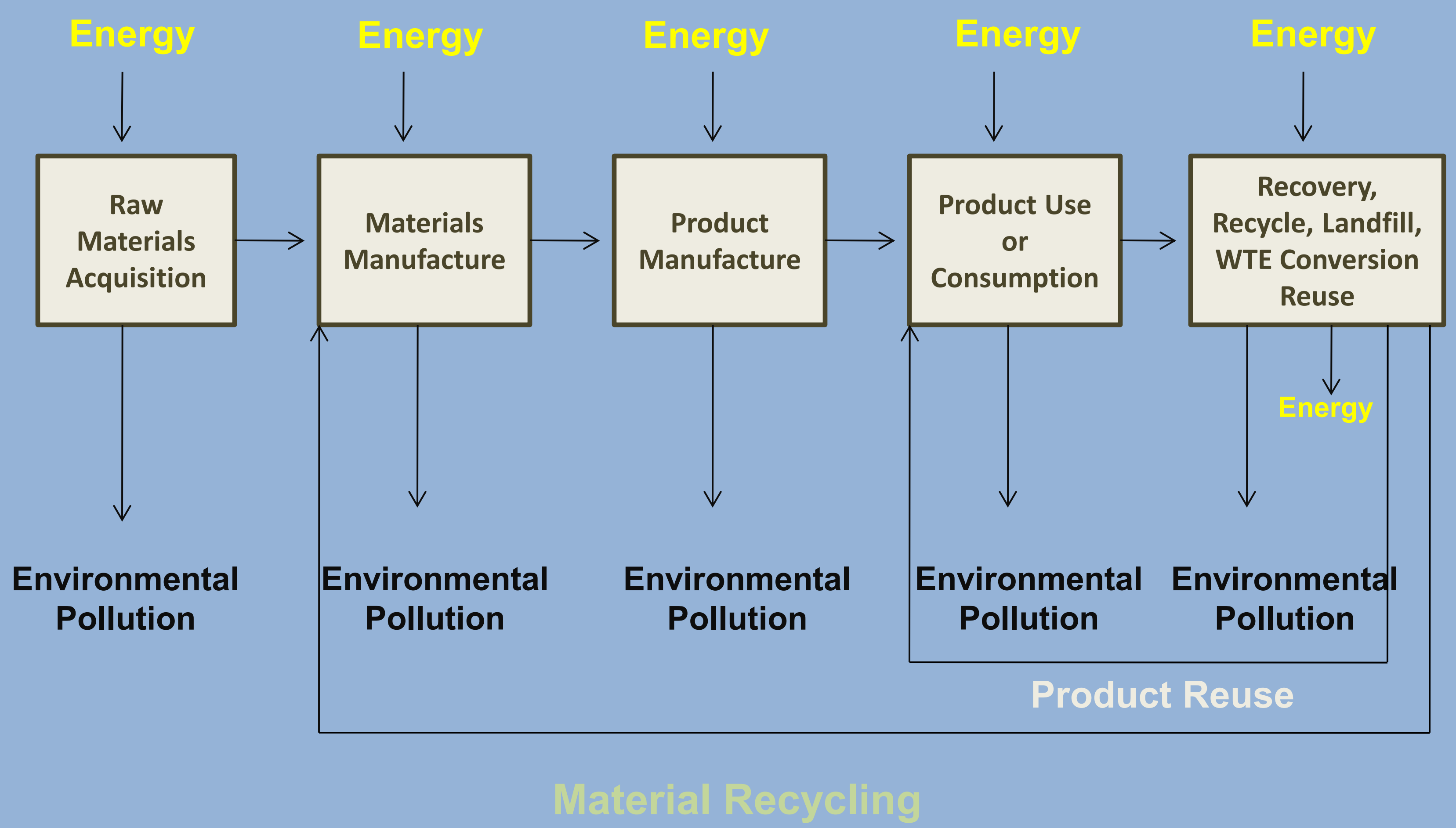
LCA vs. Cost Accounting

- **Product market price reflects rolled up costs of activities along the supply chain – i.e., resource extraction/refining, manufacture, transport and marketing costs**
- **Product price typically does not reflect use or end-of-life (EOL) costs or costs of pollutant emissions**
- **LCA product impacts = rolled up supply chain pollution emissions impacts (aka “upstream” impacts)**
- **LCA product impacts also may include use and/or EOL impacts**

Schematic of a Product's Life Cycle

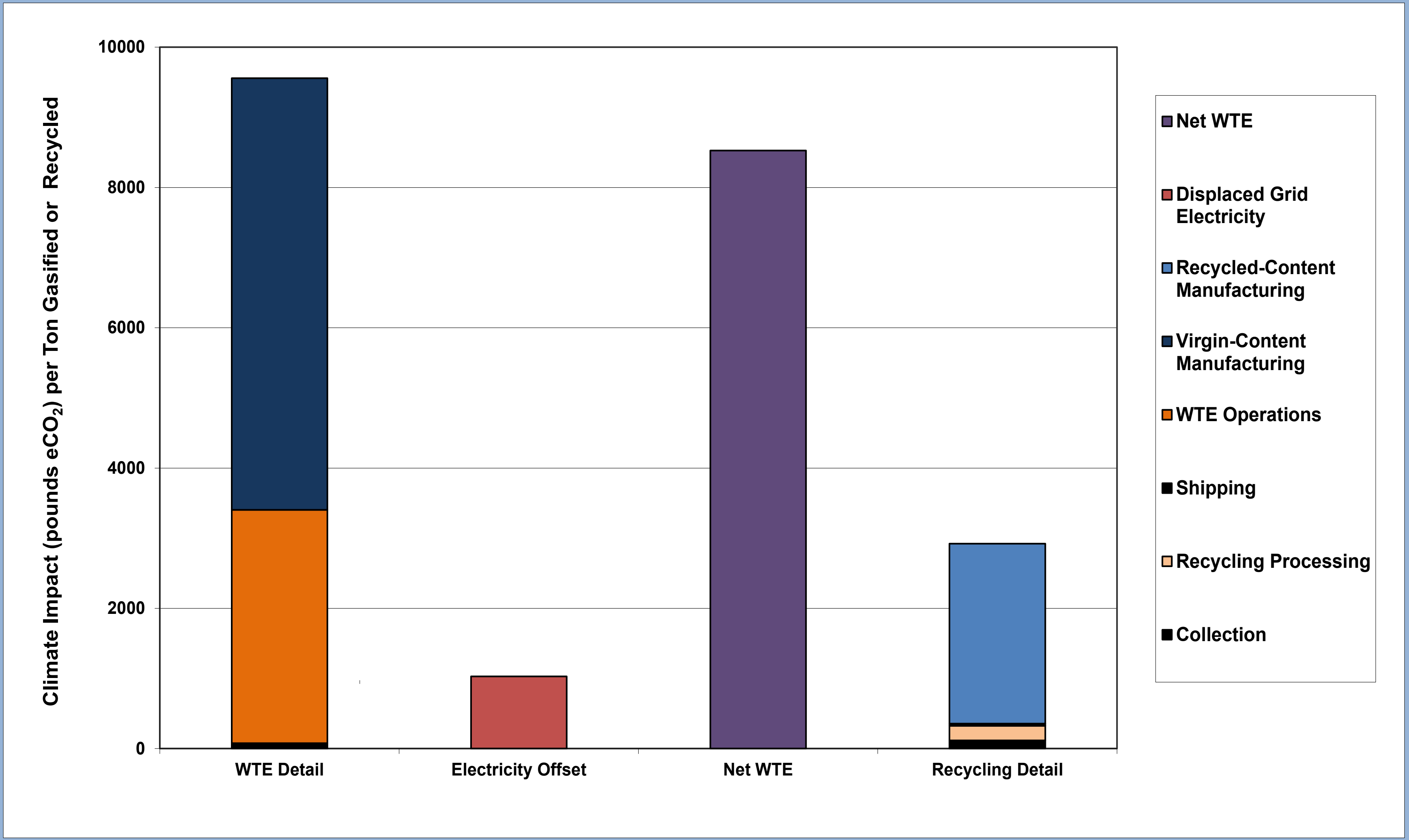


Important Aspects of LCA

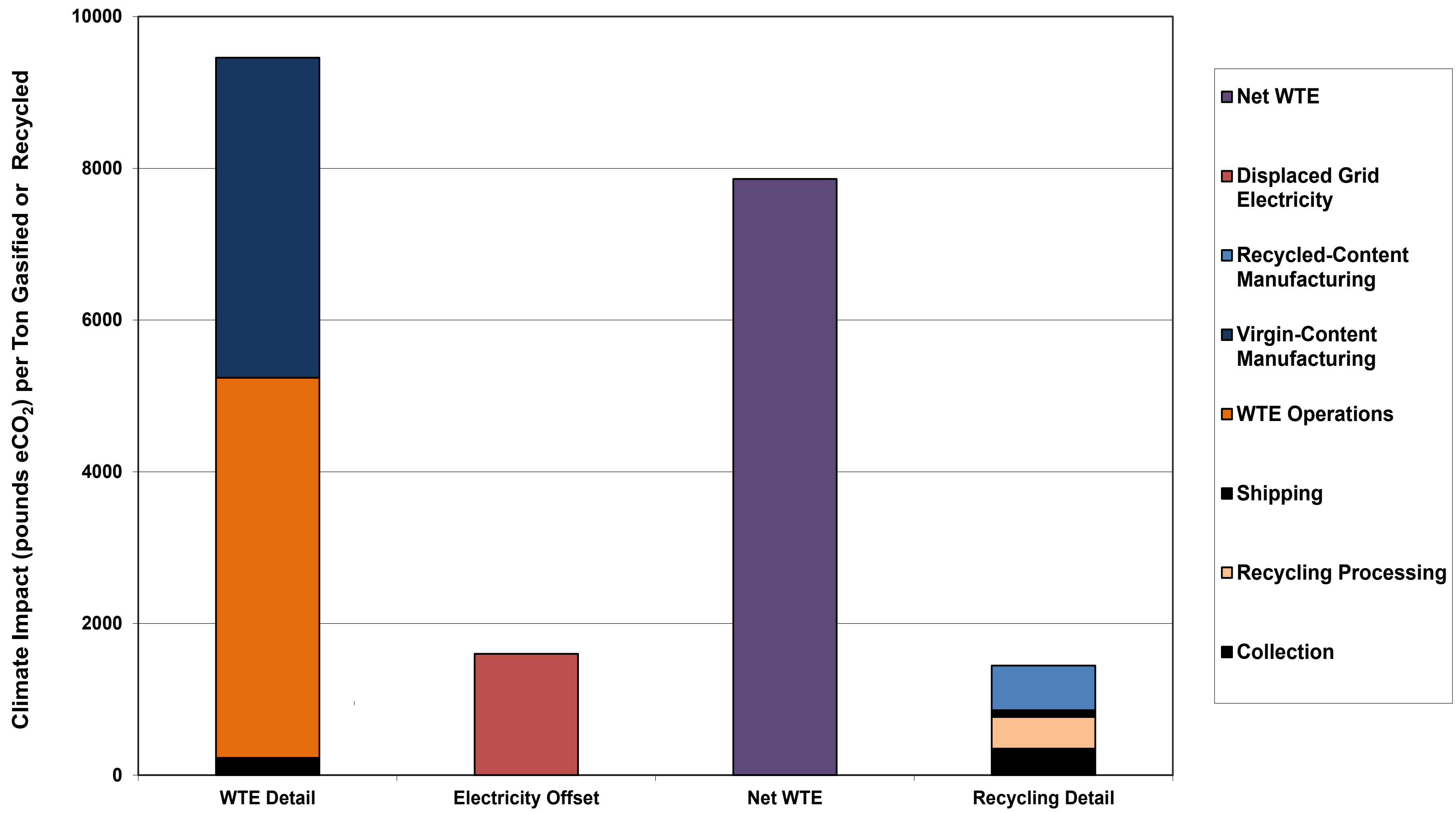
- **Accounts for pollution impacts that – because of free disposal of pollutants into/onto air, water, and land – are not reflected in product prices**
- **Indexes numerous damages from hundreds of pollutants into a few big-picture environmental indicators for climate change, human health, and ecosystem/species well-being**
- **May report other metrics – e.g., primary energy, mineral resource, land, and/or water use**
- **Includes material and/or energy offsets when evaluating options for managing discards**

Example: Upstream Typically More Important Than Trucks & MRFs

WTE vs. Recycling Climate Impacts Paper & Cardboard



WTE vs. Recycling Climate Impacts
Film Plastic (LDPE)



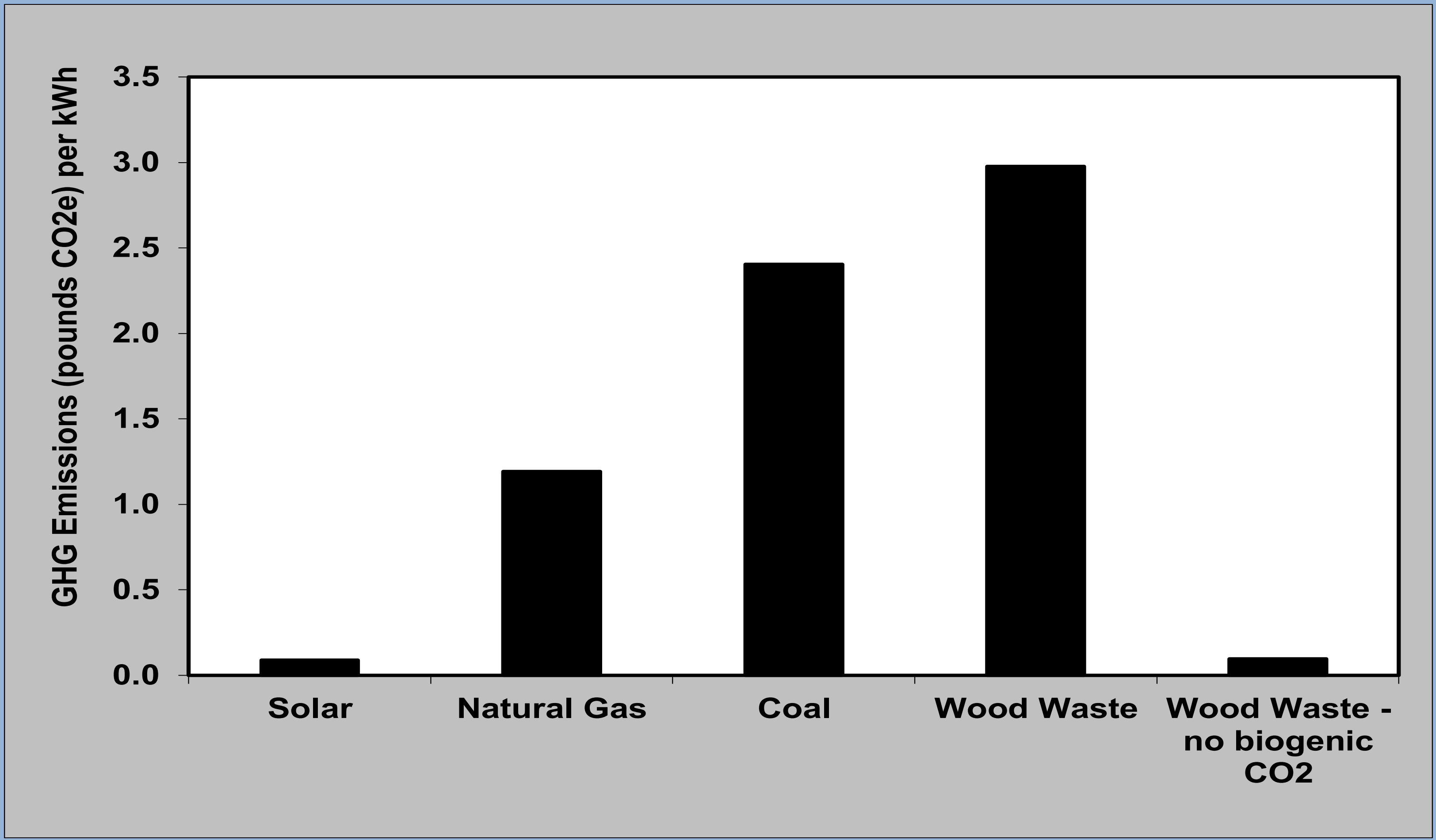
Issues in Using LCA

- **Methodology affects results – e.g., biogenic carbon accounting; average vs. marginal impacts; inventory vs. comparison of management options**
- **Presumptions affect results – e.g., options comparisons are almost always conditional (i.e., there is no always correct waste management hierarchy)**
- **Uncertainties affect results – e.g., robust, random sampling based emissions profiles for waste management activities are seldom available**
- **Evaluation of different environmental indicators affects results – e.g., how much more important is climate change than human cancers or ecosystem toxicity?**

Methodology Example: Carbon Footprint/Climate Change Accounting

- Count Biogenic Carbon Dioxide (CO_2) Emissions?
- Account for carbon emissions timing?
- Account for carbon storage?

Carbon Footprints for Electricity Generation

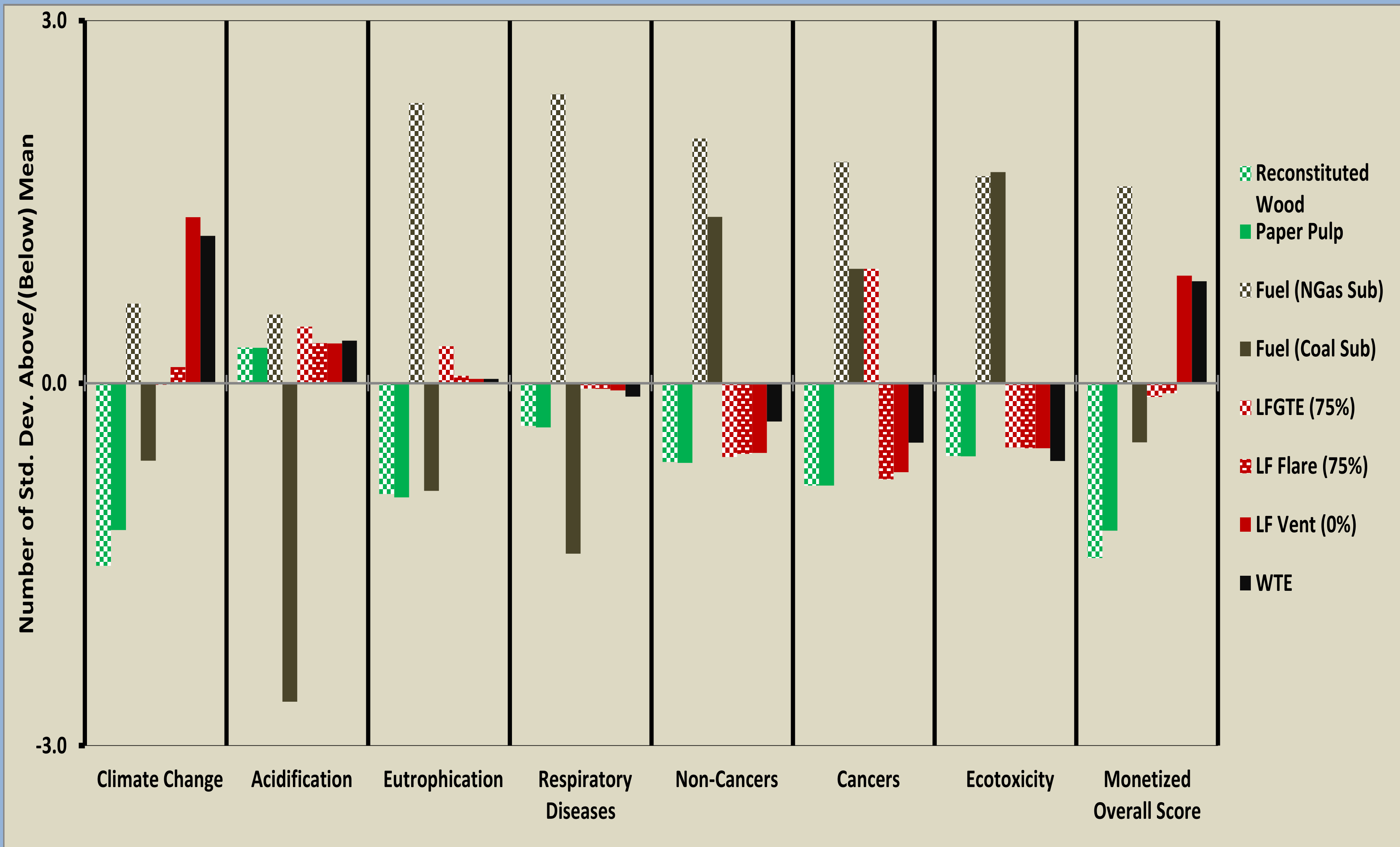


Sources: Kim, H. C.; Fthenakis, V.; Choi J-K.; Turney, D. E., 2012. Life Cycle Greenhouse Gas Emissions of Thin-film Photovoltaic Electricity Generation – Systematic Review and Harmonization. *Journal of Industrial Ecology* 16 (S1): S110-S121; Morris, J., 2010. Bury or burn North American MSW? LCAs provide 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.

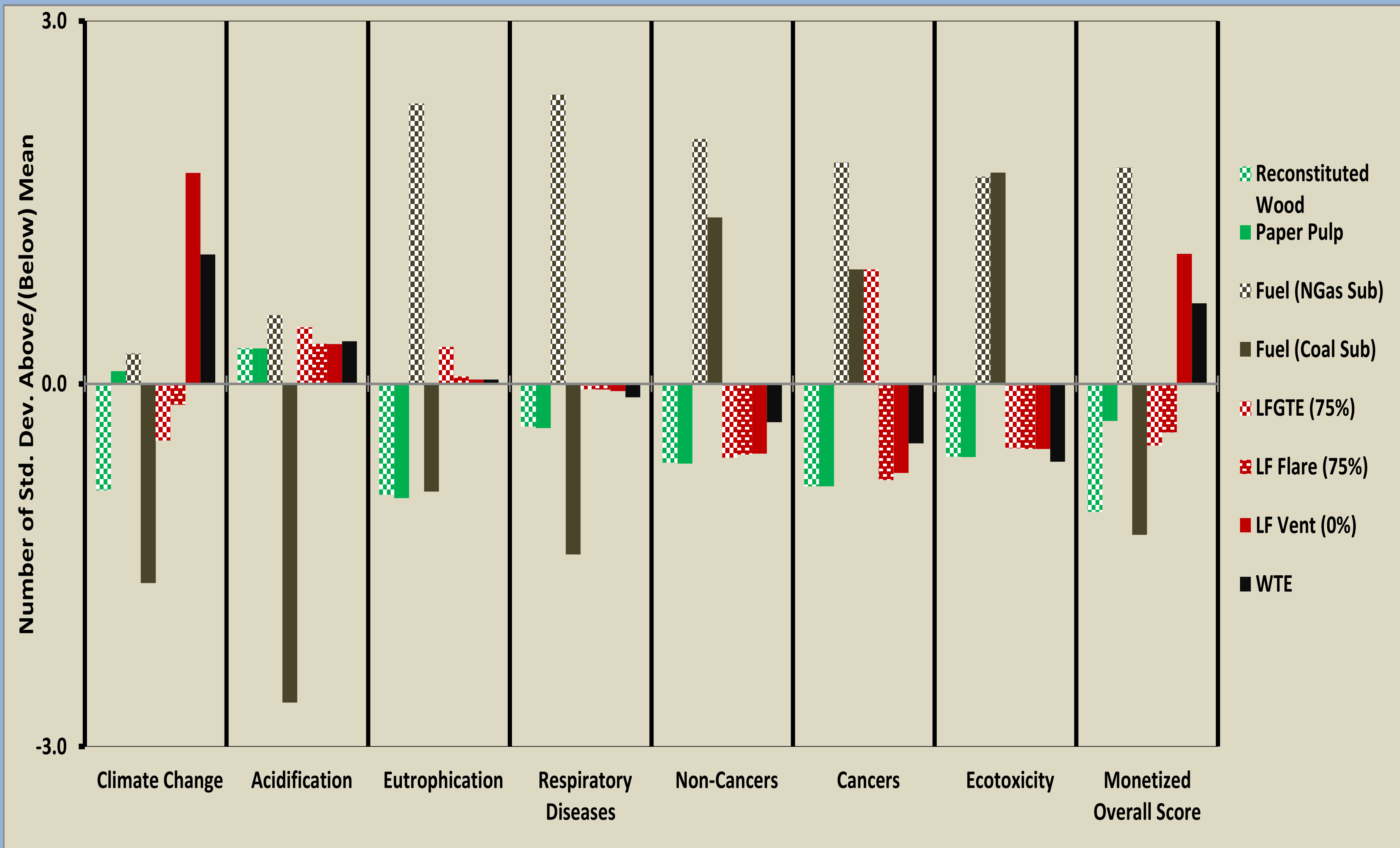
More Examples: Methodology, Assumptions & Conflicting Indicators

- **Carbon accounting again**
- **Presumptions regarding fuel offsets, emissions controls, and landfill gas capture**
- **Evaluating big picture environmental impacts indicators when they don't agree**
- **Pollution location, timing, intensity & persistence**

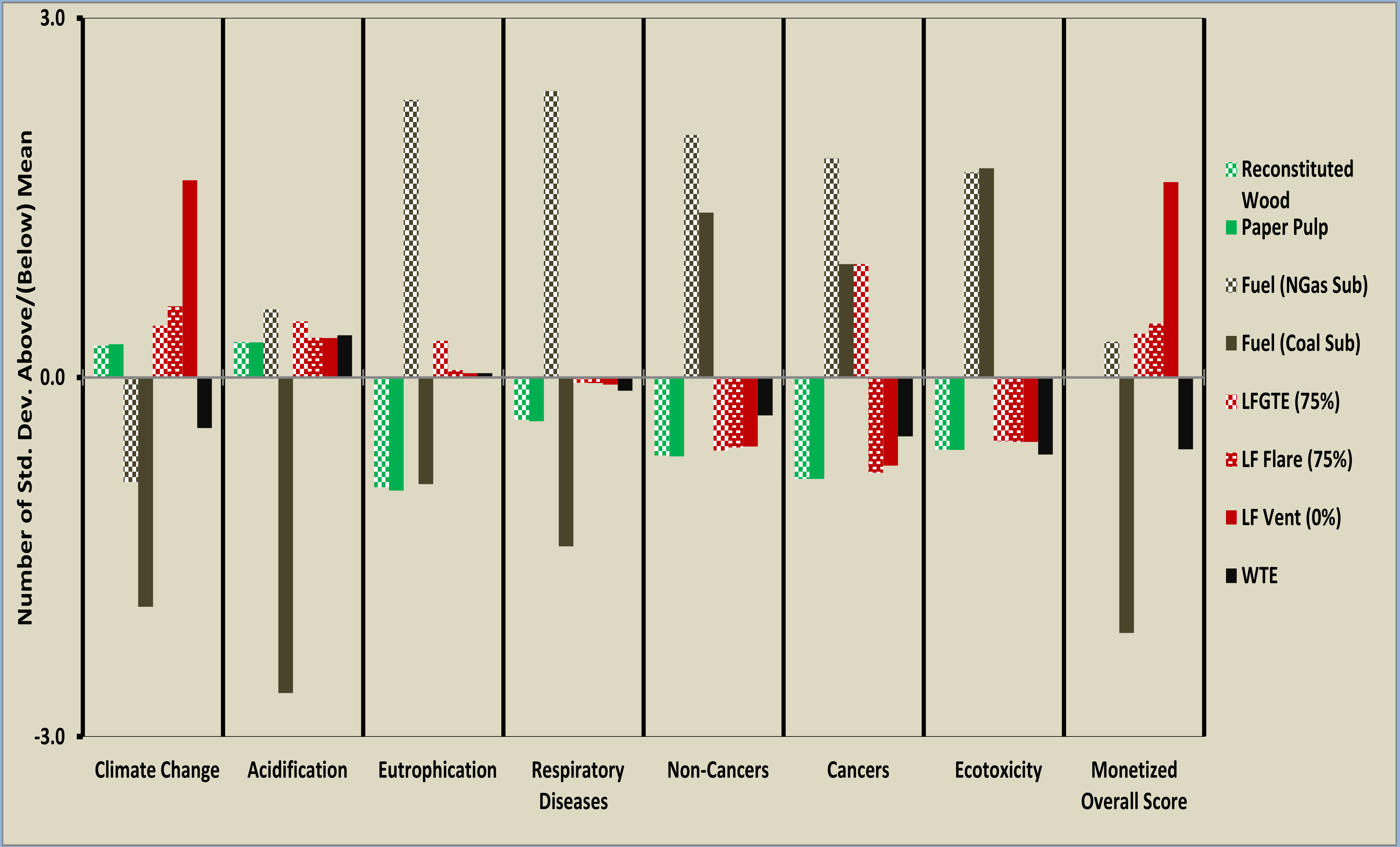
Life Cycle Impacts for Clean Wood Current Best Carbon Accounting Methodology



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

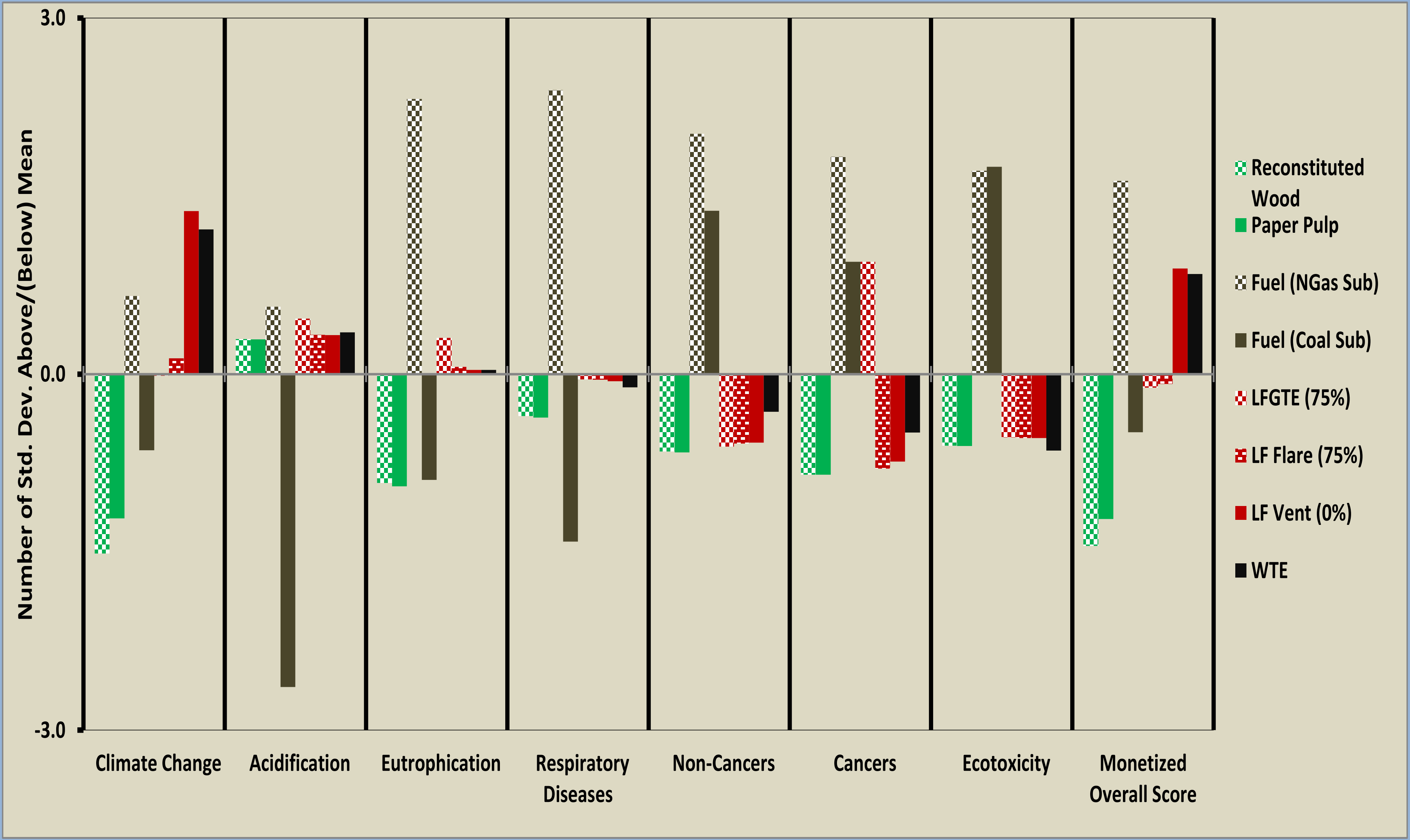
Base Case Industrial Boiler Controls (AP-42 estimates)

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

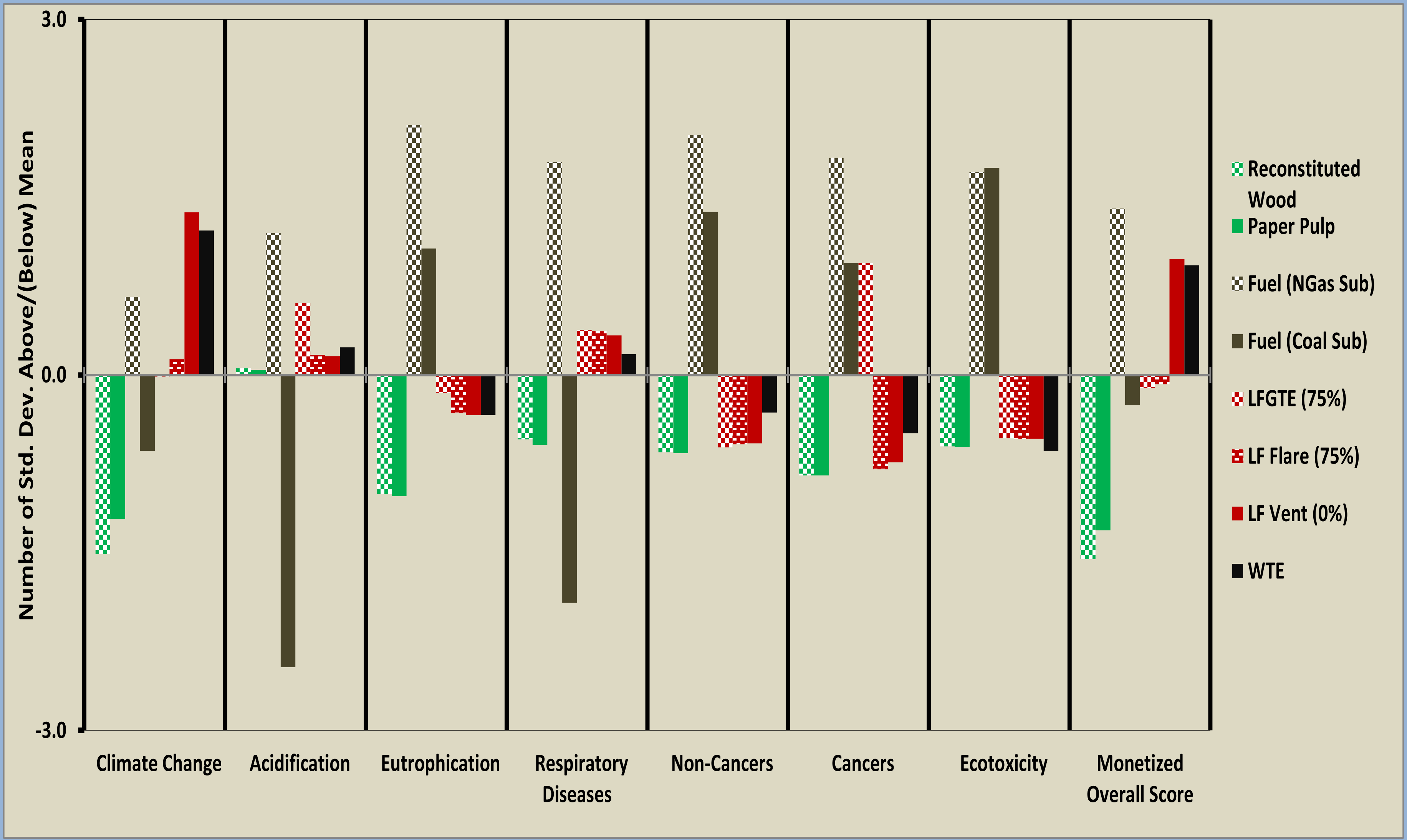
Industrial Boiler Controls for Low Emissions (AP-42 estimates)

- 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

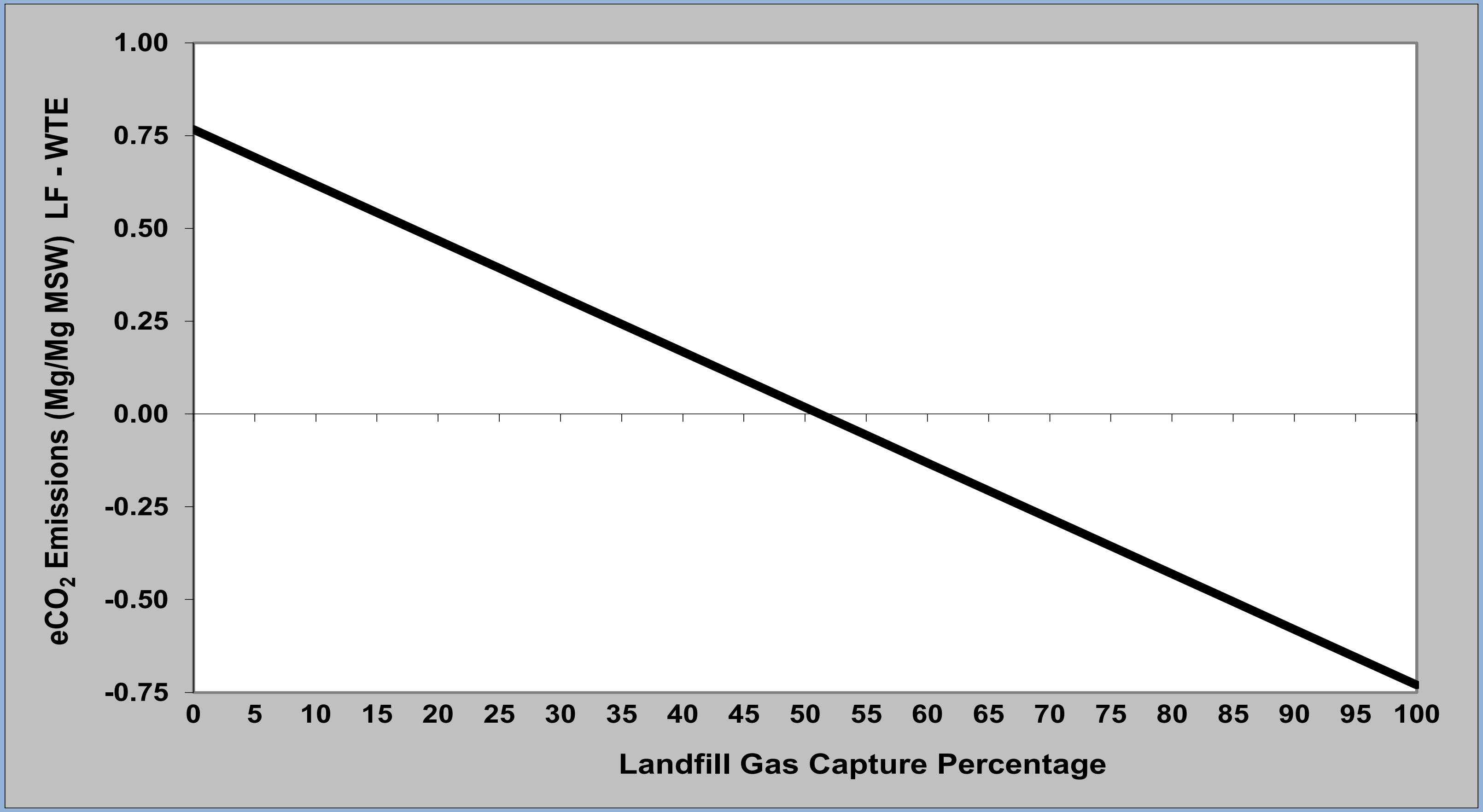


Monetization Estimates

- Climate Change – eCO_2 @ $50 per ton
- Acidification – eSO_2 @ $290 per ton
- Eutrophication – eN @ $4 per ton
- Human Health-Respiratory – $ePM_{2.5}$ @ $10,000 per ton
- Human Health-Non-Cancers – eToluene @ $30 per ton
- Human Health-Cancers – eBenzene @ $3,030 per ton
- Ecotoxicity – e2,4-D @ $3,280 per ton

Sensitivity to LFG Capture Rate

Carbon Footprint for Electricity Generation from MSW – Bury (LFGTE) vs. Burn (WTE)



Source: 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.

Note: Carbon footprint calculation includes landfill carbon storage but excludes biogenic carbon dioxide emissions.

Sources

- Morris, J., 1996. Recycling versus incineration: An energy conservation analysis, *Journal of Hazardous Materials*, 47 (1-3 Special Issue on Energy-from-Waste): 277-293.
- Morris, J., 2005. Comparative LCAs for curbside recycling versus either landfilling or incineration with energy recovery. *International Journal of Life Cycle Assessment*, 10(4): 273-284.
- 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.

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