



STRATEGIC ANALYSIS

Hydrogen Technologies Experts Meeting

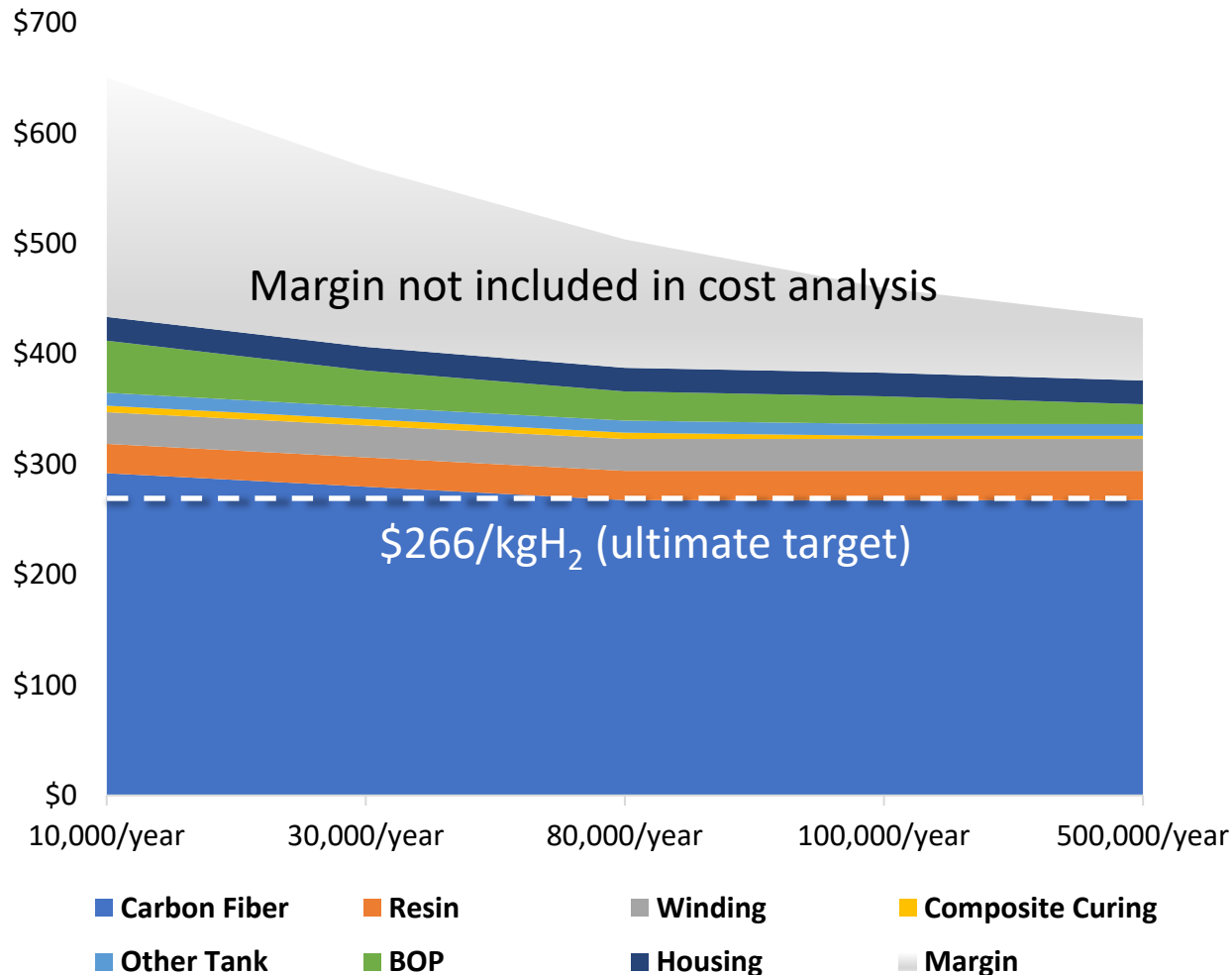


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COPV Cost Considerations

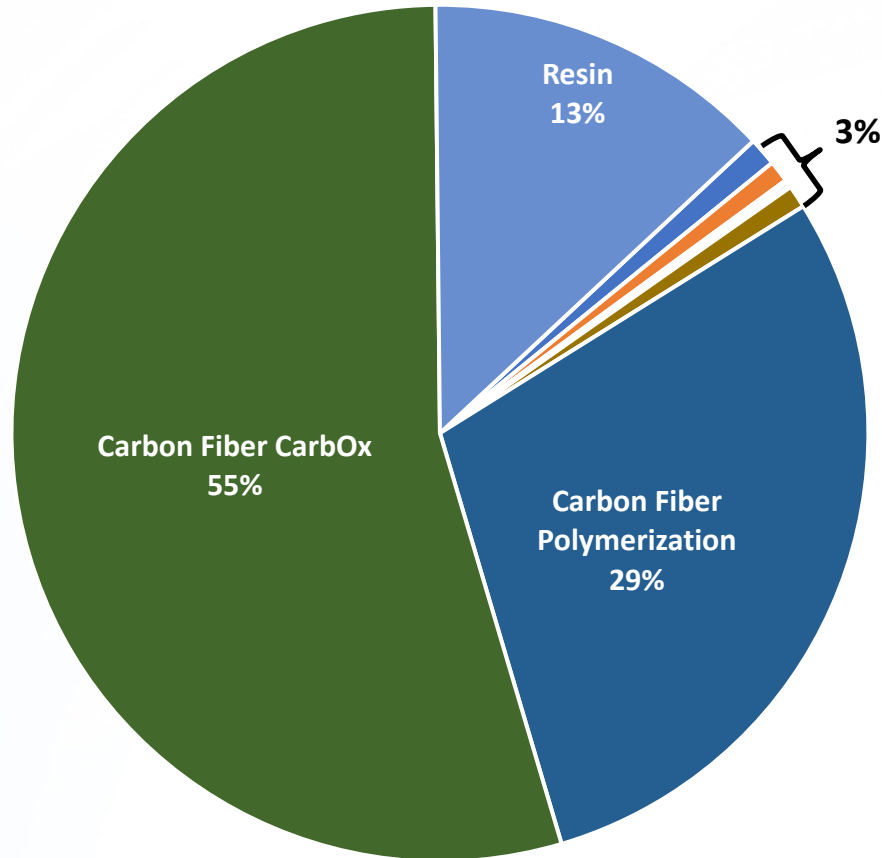
700 bar Type 4 Hydrogen Storage System Projected Costs
Frame-Mounted Class 8 Truck with 60 kgH₂ Usable Capacity



- **Manufacturing cost reductions**
 - We don't see a path to significant storage system cost reduction that doesn't include carbon fiber cost and weight reductions
 - Turnkey COPV manufacturing lines can reduce time to bring new plants online
- **Carbon Fiber**
 - Several projects are currently underway to reduce precursor and carbonization/oxidation costs
 - Codes and standards can be relaxed to reduce required stress ratio, reducing CF mass
 - New fiber chemistries not currently covered by SAE could limit innovative COPV designs
- **Margins**
 - Shown for illustration purposes, not included in reported costs
 - Explicitly excluded in our cost models
 - New design qualification can be costly, raising costs for smaller manufacturers and in early markets
 - Qualification of new fibers

COPV Embodied Energy Considerations

Embodied Energy Breakdown
60kgH₂ Frame-Mounted 700 bar Type 4



- **Embodied energy**
 - 30 MWh per system (2 tanks, 60 kgH₂ capacity) not accounting for the embodied energy of fossil feedstock extraction and processing to produce acrylonitrile
 - Under the worst-case scenario of a coal fired power plant, that's 30 tonnes of CO₂
 - Note that CF tank has a small impact on GHG emissions compared with diesel under worst case scenario (30gCO₂/mile over 1M miles vs. ~1kgCO₂/mile at 10 mpdge)
- **Carbon Fiber**
 - The message for reducing embodied energy is the same as cost: carbon fiber intensity needs to be reduced
 - Several projects are currently underway to
 - Use alternative precursors
 - Improve material utilization
 - Reduce energy intensity
- **Recycling** should be part of a long-term strategy to reduce carbon fiber utilization

Conclusions and Thoughts for Discussion

- Carbon fiber
 - Dominates both the cost and energy intensity of COPV manufacturing
 - Recycling is needed to extend the useful life of carbon fiber
- Are there ways to reduce the COPV design cycle?
- Are there non-obvious ways that long cycle time winding and curing operations should be accounted for?