

April 22, 2011

Response to Peer Review of the Draft Report “Modeling the Cost and Performance of Lithium-Ion Batteries for Electric-Drive Vehicles” Conducted by ICF International for the U.S. Environmental Protection Agency

We have examined the peer-review comments and prepared a list of changes that we intend to make to the model and the documentation. We would like to thank the reviewers for their helpful suggestions. The design and cost model is complex and thus requires a significant amount of time to learn the various components and calculations that feed into the final result. Ideally, we would have preferred greater interaction with the reviewers as this may have helped to clear up some of the misconceptions regarding how the model works and the large amount of flexibility it allows in making the calculation.

The following changes will be made to the model calculation and documentation by July 15th, 2011. We have already expended significant effort to include liquid thermal management into our model as we had anticipated this feedback.

Changes we plan to make to the model listed from greatest to least impact on the calculated price:

1. Set the default maximum electrode thickness to be 150 microns (largest effect on EVs and possibly PHEVs) while continuing to allow the user to override with any value, perhaps to match the current practice of 75-100 microns
2. Implement liquid thermal management on all battery packs initially estimated at \$70-350/battery
3. Changes in business and financial issues to address reviewers comments loosely following Mr. Bly
4. Increase the cost of electronics for monitoring temperature, state-of-charge and balancing ~\$25/battery
5. Increase cost of tabs to account for polymer sealant and use of isolation tape ~\$25/battery
6. Changes in the capital cost of the materials preparation (lower) and coating (higher) costs that are largely offsetting in response to a more detailed review of the cost inputs from an industrial partner

Changes we plan to make to clarify questions but will make no or minimal difference in the calculated price:

1. Reemphasize the goal of the model as we feel some reviewers misunderstood the stated purpose
2. Estimation of maximum temperature rise for new liquid thermal management systems

3. Reference and discussion on the validation of the model and further justification for default inputs
4. Statement of estimated costs for components required to ensure safe operation and integration of pack into vehicle that are not currently included in battery cost model
5. Breakdown of the cathode material price into raw materials and baseline costs (processing, profit, utilities, other materials) for the oxides based on nickel, manganese, and cobalt. This will also allow the user to independently estimate the cost for any proposed NMC material.
6. Explaining the relative contribution to cost from having to license a proprietary technology
7. Discussion of what the predicted model price represents and situations where it might be conservative or optimistic
8. Increasing clarity on how to use the spreadsheet
9. Clarification of the production volume scaling methods
10. Discussion of where waste management costs (waste water, etc) are included in the estimation
11. Reemphasize that all default values may be overridden and work to minimize embedded values
12. Explanation of approximate method to account for modules, composed of the same cells, connected in parallel
13. Cell thickness will be changed to better fit the large range of PHEV type cells needed. It will either be based on power, power-to-energy, or enabled to accept a user-defined value.

We offer a brief response to the general comments regarding the calculated price and default inputs into the model. The battery pack price to the OEM calculated by the model inherently assumes the existence of mature, high-volume manufacturing of Li-ion batteries for transportation applications. Therefore the increased costs that current manufacturers face due to scale-up, higher than expected cell failure in the field, and product launch issues are not accounted for in the calculation. The model results for year 2020 could be considered very optimistic if the transportation Li-ion market fails to develop as a result of insufficient investment in product research and development, reduced motivation for lowering petroleum consumption and green house gas emissions, and/or a series of high-profile safety incidents. However, we do not believe the assumptions made in the model are unreasonable and certainly are not universally questioned by the reviewers. Indeed many aspects of the model have been simultaneously supported and criticized by the panel. This model is using materials that are currently commercially available today, to predict battery pack costs in the year 2020. As Mr. Kelty pointed out, materials are the largest single sources of cost to the battery pack. Therefore, the largest individual contributions to the battery pack price could reasonably be considered conservative. New active materials are already gaining interest and being considered for the next generation (~2015) of PHEVs and EVs. These higher energy density active materials will lower the contribution of materials to the total price of the battery. We have not included estimates for these new materials as the final performance characteristics have yet to be established.