

RECOMMENDATIONS FOR ARPA-E ACTIVITY ON ELECTRIFICATION OF TRANSPORT

Personal, unofficial opinions only; Dr. Paul J. Werbos (http://www.werbos.com/CV_2009.pdf)

SUMMARY

In order to fulfill ARPA-E's mandate under PL 110-29, the requirement here is to do research which reduces our dependence on oil imports and our CO₂ emissions as soon as possible. In practice, that means making plug-in hybrids with longer range, and perhaps true electric cars, economically competitive and effectively mass-marketed as soon as possible. There are three main areas where research can make a maximum contribution to addressing the real obstacles:

- (1) Minimizing the cost per kwh of effective storage for batteries which otherwise meet the requirements for automotive use;
- (2) Making it possible for the car industry to actually use the lowest cost batteries, by developing open-access battery models capable of predicting battery lifetime and the possibility of catastrophic failures as a function of battery management – so that data and models can be developed as required for the development of more powerful battery management systems;
- (3) Combining (2) with work on the smart grid and empirical work on new practical recharging strategies (such as “pulsed recharging”) to upgrade the designs and standards for small recharge stations.

As one part of this effort, I would recommend that ARPA-E negotiate a memorandum of understanding (MOU) with the National Science Foundation (NSF), structured like the one which led to the earlier joint program with NASA, <http://www.nsf.gov/pubs/2002/nsf02098/nsf02098.pdf>. In this case, ARPA-E should commit at least \$20 million per year to an open solicitation to all US universities, small businesses and other eligible parties. While the NSF machinery for processing proposals and awards and setting up review should be used, a joint working group of ARPA-E and NSF program Directors should manage the effort, and the ARPA-E program officers should have direct selection authority through the NSF machinery in allocating the ARPA-E funds. DOD may also be interested in joining and kicking in. This kind of system gives the advantage of more access to a wider pool of ideas, and a faster and easier machinery for getting money out the door.

The battery part of the joint program announcement should refer to two important recent workshops which directly address the “middle ground” which ARPA-E is looking for here: <http://web.mit.edu/dsadoway/www/>; <http://www.almaden.ibm.com/institute/>. There is a very informative detailed report from the Sadoway workshop which they would probably agree to post for the public if you asked.

BACKGROUND

On a personal level – I worked for ten years as lead analyst for the long-term future at EIA/DOE before twenty years running technology R&D programs of many sorts at NSF. That has given me some unique information about where the unmet opportunities are and what it takes to capture them. I have also worked for years on a volunteer basis through IEEE, the world's largest engineering society, to advance the goals APRA-E is charged to advance; for example, see the talk I gave last year at the Energy Summit in October (www.werbos.com/E/500mpg.pdf). The interest in that talk resulted in all-expenses trip to Nagoya, where I spoke to the folks developing all the Toyota hybrids about what the real requirements are to get more plug-ins on the road faster. In another follow on talk in China, http://www.werbos.com/E/China_IV_Break_Oil.pdf, I elaborated on the strategy and reported what I heard from Toyota (and showed a picture to prove what I just said). Through IEEE, I have received input (some proprietary) from many key engineers in industry – see <http://www.ieee-cis.org/technical/isatc/alternative/>.

The importance of battery cost is basically a no-brainer. Because hybrids and plug-in hybrids have lower fuel costs than conventional cars, and because they are just as good if well-designed, it's the extra cost of the cars that's the main problem. Even for conventional cars, at least 2/3 of that extra cost is the cost of the batteries. Make the batteries bigger (as needed for plug-ins), and the cost and capacity of batteries becomes even more important.

Without getting into proprietary information – there may already be batteries out there with costs half or less what the best US manufacturers are trying to sell to the auto companies, which the auto companies cannot use because they must meet high standards of expected lifetime and proven low incidence of catastrophic failures. (By “catastrophic failure, I don’t mean ordinary battery failure, but events like explosions that could cause very expensive liability payments and bad news.) That’s where battery management comes into it. There are few companies who have been accumulated interesting proprietary databases of huge value for one or two battery types – but we could do a lot more. Also, there are technologies from computational intelligence which could allow more universal and adaptable battery management systems, if only the supporting data and models were more available.

As for recharge – it can have a huge benefit for national security, in addition to what it does to sell more cars (which Toyota says is already large). If you have a 40-mile-range plug-in hybrid, and your job is 30 miles away, you could still get to work every day **even if US access to gasoline were totally eliminated, so long as there in a convenient recharge station at or near your place of work.** That’s not just a research issue, but research could help, so long as it linked somehow to the parallel efforts to develop (evolving) new standards.

With regard to the two workshops – the probability now seems greater than I thought that a factor of ten improvement could be achieved here – enough to enable true electric cars with enough range and low enough cost to appeal to the average consumer. Among the interesting ideas (which have taken off to some extent since then) are lithium-air batteries, as in the impressive recent work of Johnson R&D, and efforts to develop new electrolytes which may someday allow a wider choice of chemistries (like Al⁺⁺ instead of Li⁺) for car batteries. Both offer hope of also reducing Li/kwh, which has other benefits to national security. But of course, an open solicitation should give such things only as examples. Note that the iron-phosphate Li-ion battery was invented by a university professor (Goodenough) living off of NSF funding, and the most advanced lithium-air work today is at small businesses.

NSF has issued a one-time one-year solicitation on energy storage which I hope will help get these teams started... but it does not focus squarely on the needs of cars, and will not continue beyond 2010 in any case.

In another context, some of us have been discussing an unofficial draft idea on these lines:

The Secretary of Energy, the Director of ARPA-E and the Director of NSF are directed to sign a Memorandum of Understanding (MOU) by the end of 2010, which provides for a series of continuing joint programs to be funded out of the ARPA-E budget, with an option to receive and use additional funds from other sources if available and to include other interested government agencies. All such programs shall be managed within the NSF electronic proposal submission and review process, and shall be open to all universities, small businesses and nonprofit corporations in the United States, as provided for in the NSF Grant Proposal Guide with no additional eligibility rules. Notwithstanding this provision, the MOU should allow the use of mechanisms such as exclusion of proposals for which the preproposal did not pass merit review. While funds shall be transferred to NSF, actual selection authority shall go to teams of technical experts at ARPA-E and NSF, under terms to be specified in the MOU. Each joint program shall be widely announced through the NSF system, and shall be open to new competitive proposals at least once per year. There shall also be some provision for small seedling grants. Reasonable strategic thinking about future technology costs must be discussed in all proposals and review. No awards shall be for more than \$2 million total.

(a) Joint Programs

While ARPA-E and NSF (and their other partners, if applicable) may agree to other joint programs under this MOU, there shall be at least three new continuing programs which receive at least \$20 million per year in 2009 dollars from the ARPA-E budget:

- (1) **Breakthrough battery research** – Reviewers will be asked to address the following questions for each proposal in qualitative terms: (aa) “If this proposal is funded, how much will it increase the probability that in five to ten years we will have a prototype of new basic battery design suitable for use in plug-in hybrid cars (in terms of energy and power density and other parameters essential to the auto industry) which would cost half or less per kilowatt-hour of effective storage as the least expensive suitable such batteries on the market today if it gets to mass production?”; and (bb) “Alternatively, will it lead to equally important

progress in models of battery lifetime and the probability of hazardous failure, which will allow the practical use in cars of less expensive suitable batteries?" Panelists and selection committee members shall be directed to choose those proposals which are best, in toto, based on these two criteria and these criteria only, when allocating the base \$20 million from ARPA-E. This program shall continue until prototypes have been developed which reduce costs per kilowatt hour by a factor of ten, or until there is a reasonable consensus that all avenues towards that goal have been explored and there is little hope of new basic designs which offer even a 30% reduction in cost, even assuming the worst about the future cost of lithium. The increase in probability may come directly from the project or university itself, or as an indirect result of the project being funded. It should be understood and explained to reviewers that these two review criteria do tend to require that work be transformative in nature, and that the possibilities for broader benefits are immense.

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I wish you all the best of luck in this truly urgent, unique and essential effort.