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Subject: DOE-QTR RFI

In response to Item "5 - Crosscutting Questions" of the Department of Energy Quadrennial Technology Review Framing Document, Umicore has the following comments:

2) How do we balance international competitiveness against international cooperation?
There is an example Umicore recognizes from its own experience, where international collaboration is the core of the projects covered. That is the European Commission FP7 research programs. The Seventh Framework Programme (FP7) bundles all research-related EU initiatives together under a common roof to reach the goals of growth, competitiveness and employment. Further details available at http://cordis.europa.eu/fp7/home_en.html . Umicore is actively committed to several of such programs, which broaden the scope of work and collect expertise from different viewpoints. We find this a very enriching experience.

Collaboration can also be at a national level; e.g. in Germany where Umicore is a member of the Development Plan for Electric Mobility. The Plan intends to speed up research and development for battery electric vehicles as well as the market preparation and introduction for those vehicles. Ultimate target: 1 million EV's on the road by 2020.

Programs such as these assist Umicore in defining its own materials development.

3) What principles should the Department follow for allocating resources among technologies of disparate maturity and potential time to impact?
Put in place *across the board* a defining strategy that integrates both materials development and recycling. This "closed loop" model ensures that whatever the level of maturity, the resources will be put to the best use.

d) What are useful metrics to guide DOE technology activities?

- **Increased energy efficiency**
- **Lower environmental impact**

Wherever possible, use quantitative metrics that clearly link to the objectives of the programs as well as to general sustainable development principles. These metrics should measure the progress made relative to the starting point and can have their origins in engineering sciences. These could be energy efficiency and environmental impact metrics; for example, the categories used in Life Cycle Analysis:

- **Green house gas potential**
- **Emission of hazardous substances**
- **Recycling of waste streams (e.g. recycling of wastes from the production of energy materials or technologies or recycling of process water)**
- **Or amount of waste that cannot be recycled.**

Furthermore a combination of different metrics will be necessary to cover all aspects of technology performance.

An example from our own organization: Umicore Battery Recycling has evaluated its recycling process for battery materials versus primary production of battery materials by using *exergy* as a metric (besides other metrics in the technology development phase), to express preservation of material quality as well as the lower use of energy resources. The two items are linked as the recycling of batteries preserves the material so it can be used for new batteries, it avoids the mining of virgin materials (at high energy cost) and it preserves the efforts (energy) invested in the battery material during mining and processing in its first life cycle. Furthermore the high purity of the materials in the used batteries means that less effort (energy) is necessary to obtain high-quality materials again. Umicore combined this with a highly energy-efficient recycling (smelter) technology, which uses as little energy as possible. See "The global life cycle of rechargeable Lithium ion batteries: what natural resource savings can be gained through recycling?" - Jo Dewulf, Ghent University together with Umicore htp://www.batteryrecycling.umicore.com/download/show_LCM2009CapetownJoDewulf.pdf

7) Have we correctly identified and structured these six strategies?
A critical component that we do not see incorporated here is acknowledging the role of the supply of materials in achieving the goals of the strategies, and as a consequence the energy needed to mine, refine, manufacture (= supply) the materials is not taken into account. The demands for energy and materials are closely interlinked as it takes energy to produce the materials that can enable the clean energy future. *Recycling of metals requires much less energy* than their primary production, *hence recycling is a core technology in achieving a clean energy society.*

Recovering metals from production scrap and waste and from end-of-life products needs much less energy than production from primary resources. For aluminum for example, recycling uses only 25% of the energy demand for virgin aluminum production, hence produces also 1/4th of the CO2 emissions. For the more noble metals such as cobalt, the platinum group metals and metals such as indium, tellurium or selenium the energy savings made by recycling the metals can be even larger. Therefore recycling is a core energy technology. Producing metals via responsible recycling means that the industry will emit less CO2 and the possibilities for new recycling industry and associated manufacturing industry in the U.S. can increase. The energy demand in the industrial sector will be lower as well. In addition, further advancements (innovation) in the energy efficiency of the recycling processes can drive down the energy consumption further, resulting in a "double gain" in the field of energy savings.

This leads Umicore to recommend that the DOE include in all its R&D programs, across the six strategies:
1) the notion that recycling of materials/products and energy-efficient production of metals and materials reduce the demand for energy, thereby serving as the underpinning of a sustainable long-term policy around clean energy technology research
2) a life cycle and systems approach to the evaluation of the reduction in energy usage over time
3) the notion that the materials, devices and/or technologies developed need to be designed from the beginning as recyclable, making certain the energy footprint of recycling is low. Or more generally, that the new technology is performing better than the current technology in all aspects - holistically, in terms of energy and material usage and from the environmental perspective
4) appropriate metrics be used that support the evaluation of the performance from an energy and materials sustainability point of view
5) recycling and materials sustainability should be demonstrated.

To support the implementation of the above we suggest assigning a dedicated person who can take the lead on recycling and materials efficiency, and is responsible for embedding

this underpinning and cross-cutting theme throughout the six strategies. Although this may sound huge and a near-impossible transformation, Umicore, as a global company, is proof that such a transformation is possible. Umicore has transitioned from a company active in metals production from mining to a company that produces materials for clean technologies, and produces these metals mainly from industrial by-products and end-of-life products using highly energy efficient, clean recycling technologies. This strategic business decision has resulted in high levels of innovation within the company and has stimulated research and innovation via collaboration with many university partners and in-house R&D centers. It has created high-tech manufacturing and industry jobs. Including recycling and the concept of energy-efficient materials supply into the program offers the United States also the possibility to stimulate innovation and contribute to national and global sustainability, as well as (partly) de-coupling itself from fossil fuels and dependence on other countries for metals supplies. The end-of-life products necessary for recycling are, in many cases, already located within the United States.

Please see also our response to item 8 for examples of how Umicore is already working within the six strategies.

8) <u>We welcome comment on the selection of these technologies and sources, as well as suggestions of alternate technologies and sources, and updated technology, cost and forecast data, particularly in rapidly-moving fields.</u>
Umicore's concerns about the need for energy efficient materials production and recycling are indicated in the items above. There are direct and indirect relations between the materials and processes in which we are involved and we see value in developing a kind of network structure among all the different players in the industry: a byproduct or waste from one can easily be the raw material for another, for example. So rather than keep each entity within one box of the Six Strategies structure, we'd prefer diagonal lines connecting wherever possible.

<u>Specifically on 6.1.1.1 – Transport – Increase Vehicle Efficiency – Light-weight materials</u>
DOE mentions the stimulation of the use of light weight metals like aluminum, magnesium and other materials to reduce the vehicle weight. Further supporting our comments in section 7, we like to use this as a specific case. Despite the fact that most of the vehicle energy consumption takes place in the use phase of the vehicle, it will be important to also look at the energy investments made into the light weight materials. This implies looking at the energy efficiency of the light metal primary production process as well as stimulating recycling of the light weight materials.

Recycling of the light weight materials is not straightforward however, as the connection of the light weight material to other materials, coatings etc. influences the effectiveness of the recycling process and the material losses incurred. This is where the initial design comes in and can facilitate recycling of the materials later on. In addition, the appropriate recycling strategies and technologies need to be developed and/or improved. Furthermore, recycling lowers the energy demand of the metals manufacturing industry hence has a direct link to Strategy 6.2.1 - Building and Industrial Efficiency. All of this allows for additional opportunities for innovation and clean technology developments.

Appropriate metrics to evaluate are necessary. In this regard we can suggest reading the following in the area of magnesium and metrics:
1) "Coated magnesium – Designed for sustainability" by C.E.M. Meskers, PhD thesis Delft University of Technology, 2008.
2) C.E.M. Meskers, M.A. Reuter, U. Boin and A. Kvithyld. "A fundamental metric for recycling applied to coated magnesium" *metallurgical and materials transactions B* vol 39, no 3 pp 500-517, 2008
3) C.E.M. Meskers, Y. Xiao, R. Boom, U. Boin and M.A. Reuter. "evaluation of the recycling

of coated magnesium using exergy analysis" *Minerals Engineering* vol 20 no 9 pp 913-925, 2007.

<u>Specifically on 6.1.2.1 – Transport - Progressive Electrification of the Vehicle Fleet - Batteries</u>

Umicore has done extensive work in this field that can support deployment of one million EV's by 2015. Based on its "closed loop" business model (strategy that integrates materials development and recycling), Umicore develops material designs and materials solutions for the battery and OEM customers that contribute both to better quality and to cost reduction (lower US$/kWh) while also developing a unique recycling process for rechargeable batteries. Work is focused in the following areas – often based on funding provided by Belgian, other European, and South Korean programs.

1. **Operating a state of the art industrial recycling plant while at the same time continuing to improve its processes**
2. **Development of next generation Li Ion cathode materials (with capacity, safety, recyclability and cost as main drivers)**
3. **Development of new Li Ion anode materials (same targets)**
4. **Exploring the limits of Li Ion chemistry by combining both cathode and anode materials to make the best Li Ion battery possible**
5. **Further improving the driving range of EV's with post Li Ion battery systems, while contributing to better cost/performance**
6. **Providing a material solution to the customer through collaboration with other battery component suppliers (eg. Electrolytes, binders)**
7. **Performing safe dismantling of used batteries and providing suggestions for more optimized designs**

Research and development is the cornerstone to realize these successfully and the pilot production of batteries is key and available. In the case of Umicore, the R&D is both applied and fundamental. It is related to product and process innovation. The innovation is based on a profound knowledge of the application and a high quality network within the academic and industrial worlds.
Metrics for battery materials are related to the US$/kWh ratio by the use of less expensive and future recycled base materials and by the improvements in their capacity on both cell and system levels.

We invite your own comments and questions on the above.

April 15, 2011