ENERGY-SAVING BATTERIES – GREEN OR GREENWASH?

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ABSTRACT

Marketing claims abound for "green" or environmentally friendly batteries, frequently based on low energy consumption during float charging. Before buying into such claims, the user should find out about the bigger picture. How much energy is used in manufacturing the battery? How much energy is used in recycling the battery, and how frequently must it be recycled? A proper view of energy savings can only be achieved through a rigorous Life Cycle Assessment (LCA), which analyzes energy usage at all phases of a battery's manufacturing, operation and recycling. This paper discusses the elements of the LCA and provides an example.

Going beyond the LCA, batteries can achieve or contribute to energy savings in two other ways: through overall system design; and by enabling applications, operating modes or devices that save energy. An example of the former is the use of temperature-resistant batteries to allow air-conditioning costs to be reduced; and the latter case is exemplified by the various types of hybrid electric vehicles that are in dealers' showrooms or in development. Further examples are provided in this paper, showing that under the right conditions and with the right choice of technology, batteries can indeed provide significant energy savings.

INTRODUCTION

Going "green"

The specter of climate change has brought energy consumption into sharp focus. Governments are either taking action or considering legislation to reduce the emission of greenhouse gases and to promote generation using renewable sources. Corporations and individuals are working to reduce energy consumption in order to minimize their carbon footprint. Even for those skeptics who refuse to accept the science of anthropogenic climate change, the volatility of fossil fuel prices and the likelihood of long-term increases make energy saving a wise course.

Energy can be saved through conservation (for example, turning off a light) or energy efficiency (using a more efficient light bulb to provide the same level of illumination). The cost of energy efficiency is generally quoted at approximately 2¢ to 3¢ per kilowatt-hour—well below the retail cost of electricity, and achievable in a much shorter time frame than new generation. With this in mind, many companies have become accustomed to considering efficiency whenever purchasing devices that consume energy. Going green can improve the bottom line as well as engendering a feeling of doing the right thing for the environment.

Greenwash

When companies go green, it raises the possibility of "greenwash." The environmental marketing company Terrachoice defines this term on its website[1] and describes what it calls "The Six Sins of Greenwashing."

> **Green-wash** (green'wash', -wôsh') – verb: the act of misleading consumers regarding the environmental practices of a company or the environmental benefits of a product or service.
> —*Terrachoice*

Terrachoice's six sins of greenwashing are:

- **Sin of the Hidden Trade-Off –** Emphasizing one environmental issue while hiding a trade-off between environmental issues.
- **Sin of No Proof** – A claim is made, but without offering evidence or certification of this claim.

- **Sin of Vagueness** – Vague claims are made such as “chemical-free” (water is a chemical), “non-toxic,” “all-natural,” and “environmentally friendly.”
- **Sin of Irrelevance** – e.g. CFC-free batteries.
- **Sin of Fibbing** – A claim is made, often relating to third-party certifications, that turns out to be false.
- **Sin of the Lesser of Two Evils** – A claim trying to make consumers feel “green” about a product category that is of questionable environmental benefit, such as cigarettes made with organic tobacco.

When it comes to “green” claims for energy savings, the use of a properly constructed LCA can eliminate the possibility of greenwashing.

LCA BACKGROUND

Life cycle assessment is a “cradle-to-grave” approach for assessing industrial systems. “Cradle-to-grave” begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. LCA evaluates all stages of a product’s life from the perspective that they are interdependent, meaning that one operation leads to the next.

LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental tradeoffs in product and process selection.

The term “life cycle” refers to the major activities in the course of the product’s lifespan from its manufacture, use, and maintenance, to its final disposal, including the raw material acquisition required to manufacture the product. Figure 1 illustrates the possible life cycle stages that can be considered in an LCA and the typical inputs/outputs measured.

LCA methodology, largely described in the LCA101 report from EPA[2], is standardized by ISO 14 040 and ISO 14 044.

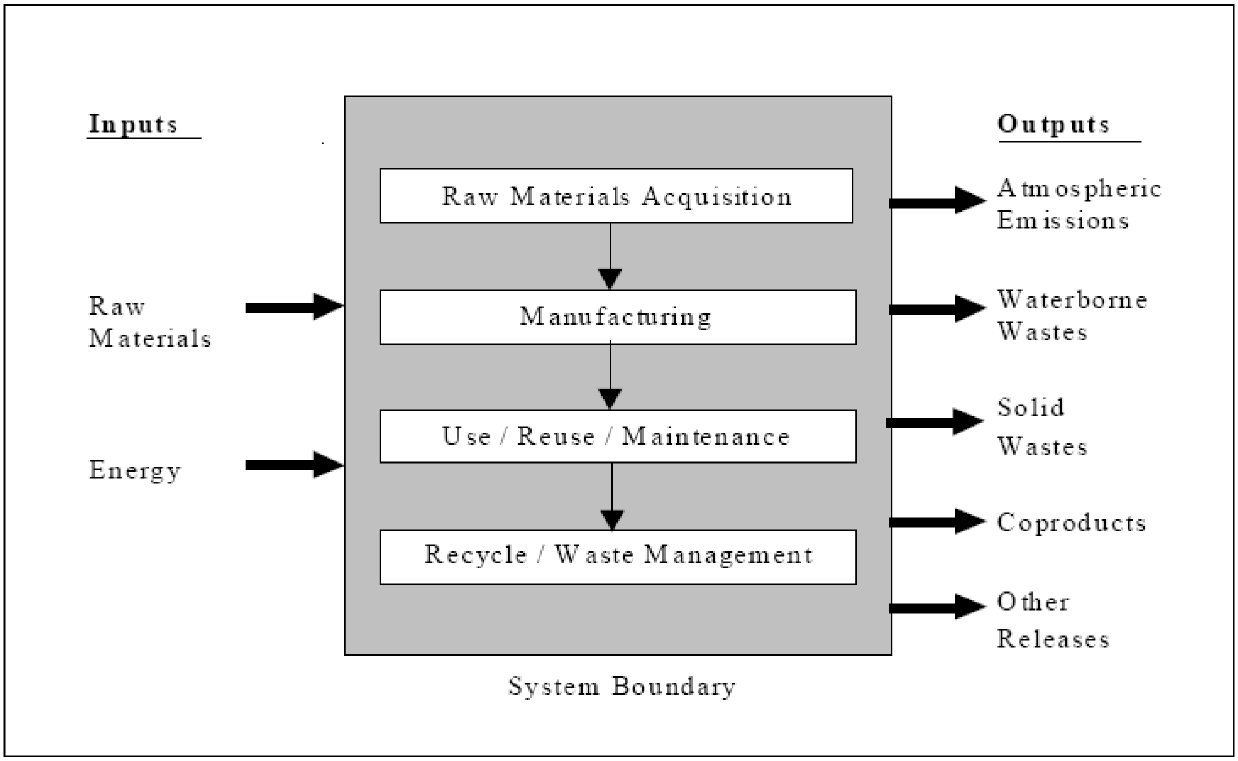

Figure 1. Life Cycle Stages (EPA 1993)

LCA AND BATTERIES

Green batteries?

In the last year or two we have seen manufacturers promoting certain lead-acid batteries as “green.” This claim is generally based on low float currents and the energy savings that result from this characteristic. To put such a claim into perspective, consider a 60-cell, 100 Ah VRLA battery: a “non-green” version might consume 100 mA on float at 135 V, while a “green” version might consume, say, 25 mA. This 75% reduction would result in energy savings of approximately 90 kWh per year. According to the EPA’s greenhouse gas equivalencies calculator[3], this would reduce carbon dioxide emissions by approximately 64 kg (141 lb)—an amount that is useful but not earth-shattering. The annual cost of electricity saved would be on the order of $10 to $15.

Going beyond reductions in float current there are more important questions that should be asked:

- **How much energy is used in manufacturing the battery?** Reductions in float current may be achieved through the use of higher-purity lead or an internal catalyst. How much additional energy is used to achieve the higher purity, or to manufacture the catalyst device?
- **Can a new battery be made from recycled lead?** The required purity may only be available from the use of primary or virgin lead, in which case the energy used in mining and extraction should be considered.
- **How much energy is used in recycling the battery, and how frequently must it be recycled?** The energy used in recycling may be considerably more than that consuming on float during the battery’s life. Obviously a longer life would contribute to energy savings.

These questions would all be answered in an LCA.

Example of a battery LCA

As sustainable development is at the core of Saft’s activity, our group is actively involved in battery LCAs[4].

One example is a comparison of Ni/Cd NCX batteries and Ni/Cd TelX batteries, which was partially presented at Intelec 2008[5]. The goal of this study is to provide a better understanding of the environmental profile of these two different battery technologies used in the telecommunication sector by means of a comparative LCA.

The functional unit (FU) is the manufacture, the use and the recycling of 80 Ah batteries over the course of a fifteen year period in an outside plant application. The battery will sustain high temperatures and the average temperature in the compartment is approximately 35 °C (the compartment is in a closed cabinet located outdoors, without air conditioning). Figure 2 shows the general system boundaries of the “cradle-to-grave” system that was considered

Several impact categories were studied:

- PED (Primary Energy Demand): total amount of primary energy extracted from the earth (in MJ).
- GWP (Global Warming Potential): contribution to the GW of the atmosphere by the release of specific gases (in kg CO_2 equ.)
- ODP (Ozone layer Depletion Potential): contribution to the depletion of the stratospheric ozone by the release of specific gases (in kg R11 equ.)
- AP (Acidification Potential): acidification by gases released to the atmosphere (in kg SO_2 equ.),
- EP (Eutrophication Potential): water enrichment in nutritive elements by the release of specific substances in the effluents (in kg PO_4^{3-} equ.)
- WD (Water Depletion): consumption of water (in kg H_2O).

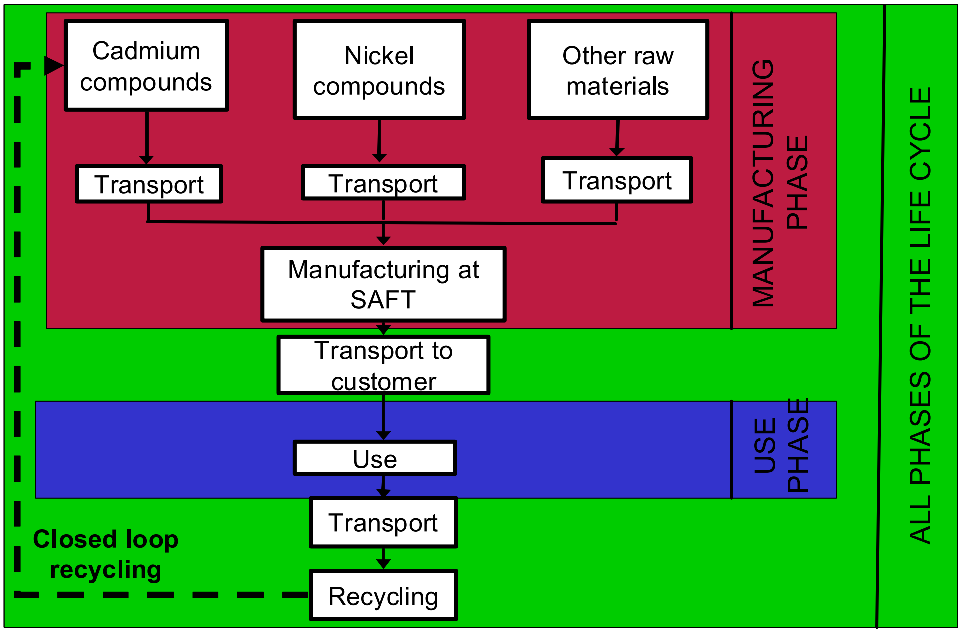

Figure 2. General system boundaries

1st scenario: from cradle to grave (without closed loop recycling)

This scenario encompasses all phases from raw material extraction to end of life. In this last phase, batteries are recycled but recycled material are not used for any purpose and therefore do not generate "impact credits". All raw material inputs are considered to be of "primary" nature.

Compared to the standard sintered positive electrode technology in the NCX battery, the new electrode technology in the TelX battery confers a significant improvement for all impact indicators, as shown in Figures 3 and 4.

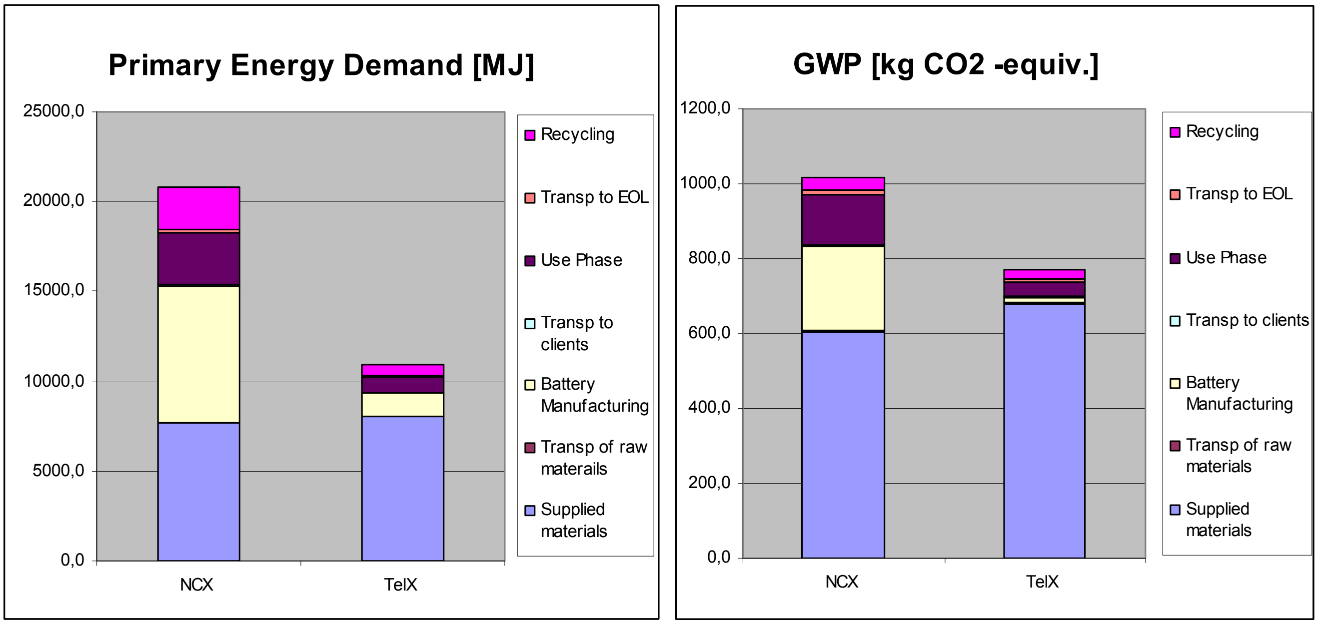

Figure 3. Comparison of Primary Energy Demand and Global Warming Potential for NCX and TelX batteries

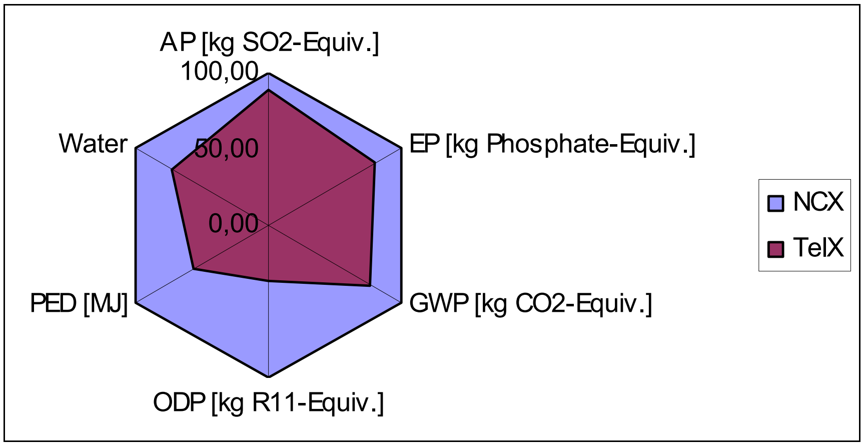

Figure 4. Comparison of all impact categories for NCX and TelX batteries

2nd scenario: from cradle to grave (with closed loop recycling)

On the basis of the “cradle-to-grave” assessment a “closed-loop” scenario was developed in which part of the “primary” metals are replaced by “secondary” materials; the secondary content in this case is 50% Cd. The environmental credits for the recovery of other materials (ferro-nickel residue) due to recycling were also considered.

With closed-loop recycling, the use of secondary material displaces the use of virgin (primary) materials and leads to significant environmental benefits both for NCX and TelX batteries as shown in Figure 5.

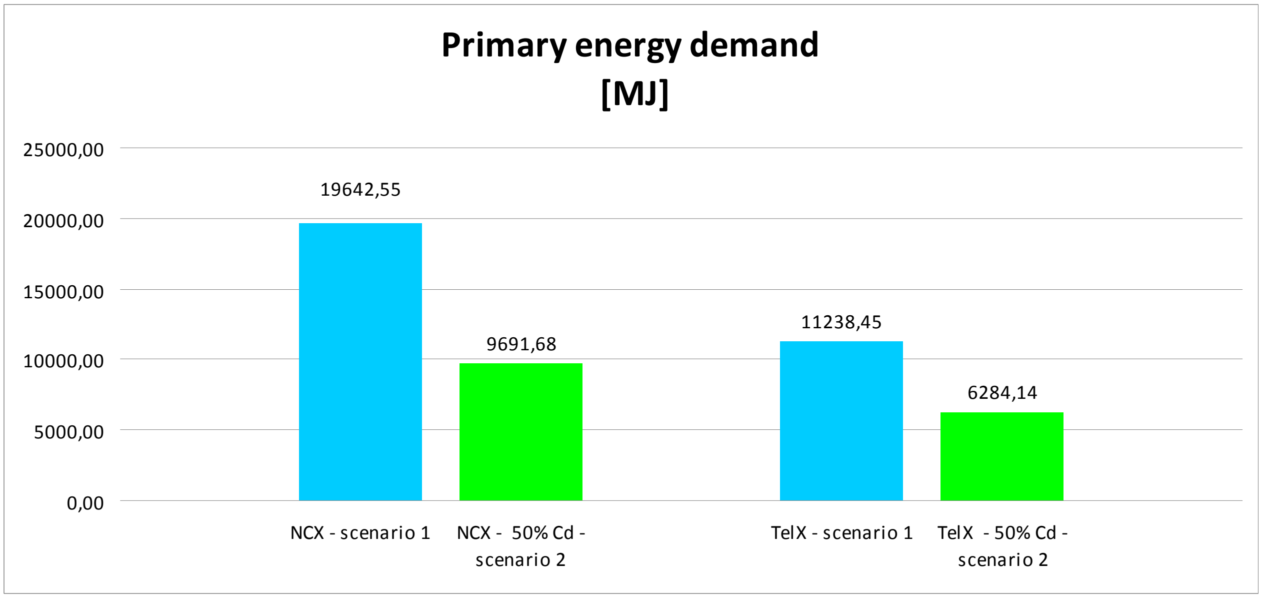

Figure 5. Impact of battery recycling on Primary Energy Demand for NCX and TelX batteries

With closed-loop recycling, batteries are much “greener” and the Primary Energy Demand of the Tel.X is highly reduced thereby making the Ni-Cd technology more sustainable and environmentally friendly.

Going beyond the LCA

As important as the LCA is, its very nature restricts it to an examination of the battery itself. The LCA does not consider the fact that a particular system design or application may enable additional energy savings to be made.

ENERGY SAVINGS THROUGH SYSTEM DESIGN

A paper presented at Intelec 2005[6] examined wireless base stations, in which the heat dissipated by the rather inefficient radio equipment requires that air conditioning be employed. VRLA batteries are typically used in this application, and to prolong battery life and minimize thermal runaway most operators set the temperature in the base station to 25 °C (77 °F). However, international standards[7, 8] require that the other equipment in the base station be designed to operate up to 40 °C to 46 °C (104 °F to 115 °F). The paper presented thermal models for typical base stations and calculated savings in energy costs and air-conditioning-unit maintenance that could be achieved by using a battery technology that is resistant to high temperatures, and by increasing the base station temperature to, say, 35 °C (95 °F). These savings were presented as life cycle costing calculations for various locations. The analysis for Phoenix, Arizona is shown in Table 1, in which it can be seen that for a 3-year payback an alternative technology such as Ni-Cd or lithium ion can cost as much as 2.8 times the cost of VRLA.

Moreover, the annual energy savings in this example work out to approximately 8 megawatt-hours, completely dwarfing the few tens of kilowatt-hours that would result from using a battery with lower float current (without changing the operating conditions).

Table 1. LCC analysis for Phoenix, Arizona; from reference [6]

Battery load (kW)	3										
Run time (hr)	2										
Labor cost (€/hr)	50										
VRLA cost (€/kWh)	190	(130€/kWh at 10-hour rate)									
Battery installation (hr)	2	(1 person, inc. travel)									
VRLA life (yr)	7										
ACU major maintenance cost (€)	1200										
Cost of money	8%										
Inflation	2%										
VRLA operating temp	25										
ACU maint. interval for VRLA (yr)	2.82	(life at 25°C)									
ACU maint. interval for alt. Batt. (yr)	4.49	(life at 35°C)									
ACU replacement labor (hr)	4	(2 people, inc. travel)									
VRLA											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Battery purchase (€)	950	0	0	0	0	0	0	1091	0	0	0
Installation/removal (€)	100	0	0	0	0	0	0	115	0	0	0
ACU replacement unit (€)	0	0	0	1273	0	0	1351	0	0	1434	0
ACU replacement labor (€)	0	0	0	212	0	0	225	0	0	239	0
ACU energy cost (€)	0	567	579	590	602	614	626	639	652	665	678
Total cost (€)	1050	567	579	2076	602	614	2203	1845	652	2338	678
Discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46
Discounted cost (NPV) (€)	1050	525	496	1648	443	418	1388	1077	352	1169	314
Cumulative NPV (€)	1050	1575	2071	3719	4162	4580	5968	7045	7397	8566	8880
Alt. Battery											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Battery installation (€)	100	0	0	0	0	0	0	0	0	0	0
ACU replacement unit (€)	0	0	0	0	0	1325	0	0	0	1434	0
ACU replacement labor (€)	0	0	0	0	0	221	0	0	0	239	0
ACU energy cost (€)	0	362	369	376	384	392	399	407	415	424	432
Total cost (€)	100	363	371	379	388	1942	405	414	423	2106	442
Discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46
Discounted cost (NPV) (€)	100	336	318	301	285	1,322	255	242	229	1,053	205
Cumulative NPV (€)	100	436	754	1055	1340	2662	2917	3159	3388	4441	4646
'Break-even' battery cost (NPV) (€)	**950**	**1139**	**1318**	**2664**	**2822**	**1918**	**3051**	**3885**	**4009**	**4125**	**4234**
Cost (€) / kWh	**190**	**228**	**264**	**533**	**564**	**384**	**610**	**777**	**802**	**825**	**847**
Multiple of VRLA price	**1.00**	**1.20**	**1.39**	**2.80**	**2.97**	**2.02**	**3.21**	**4.09**	**4.22**	**4.34**	**4.46**

(Note: the currency figures in the table are in Euros because the Intelec paper was presented in Europe. However, the allowable price multiple in the bottom line is independent of currency units.)

ENERGY-SAVING APPLICATIONS

We are now seeing a proliferation of new battery uses in which the application itself provides energy savings or other environmental benefits.

Hybrid vehicles

Since the first Toyota Prius went on sale in Japan 12 years ago we have seen steady growth in the number of hybrids available from car manufacturers and exponential growth in the number of these vehicles on the road. In addition to the fuel savings provided by the combination of a 1 to 2 kWh battery and a small internal combustion engine, some hybrids have dispensed with a tachometer in favor of a dial showing instantaneous fuel consumption. More than a gimmick, such devices can help an already energy-conscious driver optimize his or her driving habits for even greater fuel savings.

As well engineered as the Prius and other so-called “full” hybrids are, their fuel savings are somewhat limited, especially in highway driving where the battery is essentially inactive. The next generation of hybrids will be Plug-in Hybrid Electric Vehicles (PHEV), which will offer, say, 40 miles of electric-only range from their lithium-ion batteries and will then revert to operation as full hybrids. The gas mileage equivalent of the electric-only portion should be around 100 miles per gallon.

One of the attractions of PHEVs is their interaction with the electricity network. Smart charging of large numbers of these vehicles will enable night-time wind generation to be more effectively utilized, but beyond that a two-way 10 kW connection will enable so-called vehicle-to-home (V2H) and vehicle-to-grid (V2G) operation. A V2H PHEV would allow UPS-type functionality for the home along with the ability to operate as an emergency generator.

Rooftop PV with residential batteries

PHEVs may well augment batteries that are permanently installed in individual homes, particularly if those homes are equipped with photovoltaic (PV) solar panels. The output of such panels peaks around noon—about three to five hours before the utility peak. High-cycle-life batteries will allow the solar peak output to be shifted to the utility peak and, when combined with time-of-use electricity pricing, will enable considerable savings in utility bills. Furthermore, by removing the excess PV energy input to the grid at noon when it is not needed, these batteries will actually save energy by displacing less efficient and more polluting peaking generation during the utility peak hours. The German feed-in tariffs for renewable generation have now been modified to promote self-consumption in this manner, and are likely to form a model for other countries to follow in the near future.

Frequency regulation and primary reserves

The operation of the electricity grid involves so-called ancillary services—services that must be performed in addition to the basic function of generating and delivering energy to the consumer. Two of these ancillary services are regulation—the moment-by-moment balancing of supply and demand, and primary reserves—spare capacity on the system that can be quickly ramped up in response to a disturbance on the grid.

At present, regulation and primary reserves are provided by fossil-fueled generators with no net delivery of energy to the consumer. This situation is about to change, with energy-storage systems starting to come on line to provide these services. One such system recently completed testing, with a Saft lithium-ion battery paired with an ABB SVC Light system. The ABB equipment is a Flexible AC Transmission System (FACTS) device used for voltage support in the distribution grid, and with the addition of dynamic energy storage the system will be able to provide ancillary services. The pilot system, rated at 600 kW for 15 minutes and 200 kW for 1 hour, and with the battery operating at a nominal 5200 V, will provide grid support at an EDF Energy location in the UK, where it will also be tested in conjunction with a nearby wind farm. The lithium-ion battery is shown in Figure 6. Future systems will operate at much higher power ratings and will displace generator-based ancillary services, thus enabling considerable fuel savings and reductions in greenhouse gas emissions.

Figure 6. 5200 V lithium-ion battery for grid support

CONCLUSIONS

The days are past when being an environmentally responsible battery user just meant recycling spent batteries correctly. Users are right to be concerned about the environmental impact, including energy consumption, of products that they buy. However, if they concentrate on a single aspect, such as energy consumption on float, they miss the big picture and risk being victims of greenwashing. A "green" battery should use the highest possible levels of recycled materials and its environmental impact should be properly quantified through a Life Cycle Assessment.

This paper has also shown that it is possible to save energy through the use of temperature-resistant battery technologies, thus avoiding the need for aggressive air-conditioning. Moreover, there is an expanding number of applications in which the use of stored energy in batteries reduces the consumption of fossil fuels. Whether these batteries are in hybrid vehicles, residential PV systems or are directly connected to the electricity grid, batteries are capable of delivering significant energy savings.

REFERENCES

1. *"The Six Sins of Greenwashing,"* at http://www.terrachoice.com
2. *"Life Cycle Assessment: Principles and Practice,"* EPA/600/R-06/060 , SAIC at http://www.epa.gov/nrmrl/lcaccess/lca101.html.
3. http://www.epa.gov/cleanenergy/energy-resources/calculator.html
4. Siret, C, *"Comprehensive Life Cycle Assessments of rechargeable batteries,"* Proceedings of ICBR 2008
5. Lansburg, S; Dauchier, J-M; Kitch, T; Brunarie, J and Lippert, M, *"Tailoring Advanced Ni-Cd Technology for a High Energy, Sustainable Battery Solution for Outdoor Telecom Cabinets,"* Proceedings of Intelec 2008
6. McDowall, J and Gates, W, *"Temperature up, costs down: the influence of battery technology and thermal management in base stations,"* Proceedings of Intelec 2005
7. European Telecommunications Standard ETS 300-019-1-3. *"Equipment Engineering: Environmental Conditions and Environmental Tests for Telecommunications Equipment. Part 1-3: Classification of environmental conditions: Stationary use at weather protected locations"*
8. Telcordia Technologies GR-487-CORE *"Electronic Equipment Cabinets"*