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MODEL INSTITUTIONAL INFRASTRUCTURES FOR RECYCLING OF PHOTOVOLTAIC MODULES

Paul D. Moskowitz, Sheldon J. Reaven, and Vasilis M. Fthenakis
Biomedical and Environmental Assessment Group, Department of Applied Sciences,
Brookhaven National Laboratory, Upton, NY 11973

This paper describes model approaches to designing an institutional infrastructure for the recycling of decommissioned photovoltaic modules; more detailed discussion of the information presented in this paper is contained in Reaven et al., (1996)[1]. The alternative approaches are based on experiences in other industries, with other products and materials. In the aluminum, scrap iron, and container glass industries, where recycling is a long-standing, even venerable practice, predominantly private, fully articulated institutional infrastructures exist. Nevertheless, even in these industries, arrangements are constantly evolving in response to regulatory changes, competition, and new technological developments. Institutional infrastructures are less settled for younger large-scale recycling industries that target components of the municipal solid waste (MSW) stream, such as cardboard and newspaper, polyethylene terephthalate (PET) and high-density polyethylene (HDPE) plastics, and textiles. In these industries the economics, markets, and technologies are rapidly changing. Finally, many other industries are developing projects to ensure that their products are recycled (and recyclable) e.g., computers, non-automotive batteries, communications equipment, motor and lubrication oil and oil filters, fluorescent lighting fixtures, automotive plastics and shredder residues, and bulk industrial chemical wastes. The lack of an adequate recycling infrastructure, attractive end-markets, and clear economic incentives, can be formidable impediments to a self-sustaining recycling system.

APPROACH

We reviewed developments in the above industries and from that distilled three broad paradigms that could be followed in arranging the institutional infrastructure for decommissioned module recycling. For convenience, the three model infrastructures may be referred to as the *utility model*, the *electronics model*, and the (nicad) *battery model*.

MODEL INFRASTRUCTURES

The Electronics Model

In the electronics model, decommissioned modules are treated as yet another durable consumer electronic product, like a computer, VCR, or camcorder, incorporating high-technology circuitry and advanced materials. In this model manufacturers first set up product take-back programs that generally rely on reverse logistics companies for transportation, and independent private (or in-house) dismantling facilities that themselves recycle, or take responsibility for arranging the recycling of the resulting materials streams. The transportation, dismantling, and often, the physical recycling operations are accomplished in integrated, specialized, facilities. The idea behind this model is to depend on full-service, one-stop facilities. Seeing an opportunity, some entrepreneurs are creating new hybrid services that combine these various stages and otherwise rearrange the often-overlapping functions within recycling infrastructures. On-call reverse logistics companies are ideal for arranging pick-ups of used residential and commercial decommissioned modules.

Much of the impetus for this approach comes from existing and impending European "manufacturer take-back" legislation, and in anticipation of similar laws in the United States. Many manufacturers of durable consumer products are embracing "green product stewardship" initiatives that reach throughout the product's life cycle, from designing the product for easy recycling to ensuring that recycling takes place.

There are, however, no fully functioning examples of this model. The most ambitious pilot efforts are underway in the electronics industry (here including computers, printed circuit boards, electronic communication equipment, and related products). Even so, there has been ample variation in the details of each manufacturer's plan as described in the larger report from which this paper was extracted.

One distinctive feature of the electronics model is the reliance on *reverse logistics companies*. These companies set up national industrial accounts that work like this: A residential or commercial customer ready to discard a product calls an 800 number provided by the manufacturer at the time of purchase. The reverse logistics company then pick up the item anywhere in the United States, and deliver it to the specified recovery facility. The company first may bring the product to an intermediate distribution center or storage warehouse until enough accumulates to justify a full-load shipment or route. This may entail a delay of several weeks, but that presents no problem for decommissioned modules. The pickup charge may be paid by the generator, manufacturer, or recycler, or by a fund earmarked for this purpose accumulated from purchase revenues or advance disposal fees. The reverse

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logistics business offers these companies ways to make money and avoid empty dead-head runs.

Original manufacturers of equipment can dovetail their own recovery plans with reverse logistics systems in many ways. Often, the recovery facilities accept materials derived from products made by other companies. With careful design, such dovetailing and pooling arrangements can be adapted to decommissioned modules. If photovoltaic manufacturers decide to design a version of the electronics model, perhaps the best strategy would be to piggyback decommissioned photovoltaic module recycling onto integrated recovery systems being developed in the consumer electronics sector.

The Utility Model

In the utility model, decommissioned modules are regarded as a component of the system for generating and delivering electricity -- just like a furnace, power line, pole transformer, current meter, or power plant -- irrespective of whether the utility actually owns them. In this end-user oriented model, utilities anchor the decommissioned photovoltaic module recycling infrastructure by arranging to recycle modules in their own arrays, and by directly or indirectly arranging to recycle modules on institutional rooftops and homes. Utility employees would remove old residential, commercial, and utility installation decommissioned modules from rooftops or other mountings, collecting when called, using the utility's trucks. Collecting decommissioned modules becomes a standard function of the utility, like reading meter, repairing lines, and removing trees.

The rationale is compelling. Utilities may well become the largest consumers of photovoltaic modules. They have considerable transportation equipment, including repair trucks and other vehicles that stop at homes and buildings anyway, and that could carry used decommissioned modules on return trips. Cherry-pickers, ladders, tree-trimming, brush-removal, and storm-damage repair equipment, combined with ongoing safety training programs, make the utilities very well suited to perform rooftop dismounting. Moreover, decommissioned photovoltaic module disposal services would be a logical extension of the utilities' energy conservation, retrofitting, and solarization programs. Clean Air Act Amendments benefits accrue from avoiding pollution from fossil-fuel units, and from using decommissioned modules in recharging electric vehicles, commuter-station units, and remote units. Load management also benefits in terms of meeting peak demand, reducing grid construction, and controlling power quality control.

Further, utilities already have significant experience in waste management from nuclear, coal, oil and ash management. Indeed, there may be opportunities to mix decommissioned photovoltaic module materials streams with ash from coal-fired or MSW-fired electrical generation facilities, for example, in ash-based construction blocks. Ashfills themselves could be disposal venues for some decommissioned photovoltaic module materials with concentrations of heavy metals.

Another major advantage of the utility model is the availability of tax-exempt financing for environmental projects, including solid and hazardous wastes recycling and waste disposal facilities, and ancillary projects. The Internal Revenue Service defines these terms quite broadly, so that a decommissioned photovoltaic module-related recycling and/or dismantling facility is likely to qualify. The 1986 Tax Reform Act also made privately owned facilities for hazardous waste disposal eligible for tax-exempt financing. When such financing is unsuitable, so-called project financing can be an attractive alternative.

The Battery Model

In the battery model, the decommissioned modules may be likened to very big household batteries that are "recharged" by sunlight, and similarly may require special regulatory handling. In the battery model, a consortium of manufacturers oversees a take-back program that uses dedicated collection and recycling facilities. The project is financed through member dues to the consortium, licensing fees, or other mechanisms.

The best example of the battery model is the program for recycling portable rechargeable nicad batteries. Three to four hundred million nicads were sold in 1992, more than 10% of overall U.S. battery sales. Most are used in consumer products such as cordless telephones, camcorders, power tools, two-way radios, and laptop computers; since 1993, most of these products have been redesigned so the nicads are easier to remove. Only 10% to 20% of nicads are the cylindrical alternatives to the familiar alkaline or carbon-zinc batteries. Nearly one-half of nicad production is sold to business and industry customers.

Prodded by laws in New Jersey, Minnesota, and in Europe, and by the prospect of similar regulation elsewhere, five major nicad manufacturers; Gates Energy Products, Panasonic Industrial Company, Sanyo Energy (USA), Varta Batteries, and Saft America, Inc., formed the Portable Rechargeable Battery Association (PRBA) in 1991. Smaller manufacturers, product makers, and battery pack assemblers have joined since; there were 116 members by the end of 1992. They represent more than 90% of nicad manufacturing capacity, and have the lion's share of rechargeable consumer products.

PRBA later formed the non-profit Rechargeable Battery Recycling Corporation (RBRC) to conduct the nicad recycling program. Manufacturers pay license fees that fund the program, and confer the right to place the RBRC seal on batteries and products. Commercial and institutional generators register to participate in the recycling program, and agree to return spent nicad batteries to designated consolidation facilities. The current national expansion of the RBRC program amalgamates four collection infrastructures:

1. *City and county.* Batteries accumulate at county and municipal collection centers, either by individual drop-offs or from collection at residential curbsides. They are transported from the collection centers to Consolidation Points. Under a contract with RBRC, the

operations of Consolidation Points perform any required additional sorting and send bulk shipments to Inmetco.

2. *Reverse retail.* RBRC sends participating retailers a recycling kit consisting of a point-of-sale display, plastic Zip-loc bags, handling and safety instructions, and four folded-up collection boxes that can hold 18 pounds of nicads. The retailer sets up the collection boxes, and when full, seals them with tape. The boxes come with pre-paid UPS shipping label pre-addressed to Inmetco. RBRC is seeking approval for the reverse retail program in all states.

3. *Commercial and institutional generators.* Manufacturers, police, fire and emergency service operations, and other commercial and institutional generators participate in the RBRC program by agreeing to collect their discards and ship them, at their own expense, to the nearest Consolidation Point. However, RBRC then pays the costs for consolidating them into larger shipments transporting to Inmetco, and for recycling (about 40 cents per pound). The generators and consolidation facilities exchange liability waivers and mutual indemnification's.

4. *Licensee rebates.* Licensees pay for the right to display the RBRC seal on their products. If these manufacturers arrange and pay for collection and shipment of batteries to Inmetco (not to consolidation points), they receive a rebate of 17 cents per pound from RBRC.

OTHER IDEAS

During our research we found some intriguing practices were that belong in the table of options for further consideration in designing the decommissioned photovoltaic module recycling system, but which cannot be identified with any one of the three paradigms discussed above.

Fluorescent Lights and Ballast Recycling Projects

The institutional infrastructure being developed to recycle fluorescent lights and ballasts is worth studying as an example of utilities playing a leading role in recycling, working with institutional generators of these discards. The utilities' experiences with recycling fluorescent lamps suggests contractual and logistic options. Minnesota law requires utilities to collect for recycling any fluorescent lamps that are discarded in programs for energy conservation and load management. Northern States Power has incorporated this activity in its conservation programs, including giving rate discounts and financing assistance to customers. Minnesota businesses that want to discard fluorescent lamps contact recyclers (there are two in Minnesota) who transport them from the generator to a recycling facility. Household fluorescent are consolidated at city or county drop-off sites, and at some retail hardware and appliance stores. Recycling fluorescent lamps also may be eligible for some benefits under EPA pollution prevention programs, such as its Green Lights program.

Retail-Based Collection at Home Depots

In 1993, the Home Depot chain began experiments at some outlets with a "do-it-yourself" Recycling Depot program, in a joint venture with Mindis Recycling, a division of Attwoods plc (the world's fourth-largest waste management company). Homeowners and business customers, such as plumbers and small contractors, bring gutters, electrical wire, water heaters, screen doors, plumbing parts, and other (mostly aluminum) metal scrap to a drive-through facility on the Home Depot lot. They are paid for the metal or can set up an account, and have the option of assigning revenues to charity. The pilot facility in Georgia was expected to recover 500 tons/month. Plans were being considered to add roofing debris, paints, and other construction materials that are difficult to recycle to the program. Sears has considered setting up on-site recycling centers.

Collection by Trucks Delivering Commercial Glass

Photovoltaic module manufacturers or trade associations might make arrangements for plate-glass installers to pick up decommissioned photovoltaic module discards from commercial installations, such as roofs of shopping centers. For example, the next time new panes are delivered to the shopping center, the dismounted decommissioned modules could be carried back on the empty truck. They could be delivered to a designated collection site, turned over to a reverse logistics carrier, or held at the plate-glass shop until sufficient decommissioned modules have accumulated.

Cooperative Marketing

Cooperative marketing refers to organizations created jointly by governmental authorities and various private businesses, especially in rural or low-population-density areas. Forty to sixty per cent of operating funds come from service fees, the rest from grants, in-kind contributions, and members' fees. Cooperative marketing helps to make the multi-material collection of recyclables more affordable. Three legal structures are employed; nonprofit organization, inter-municipal agreement, and resolution agreement. These vary in the formality of the contractual commitment, powers to let contracts, administrative flexibility, and availability to private businesses, as opposed to business-government mixes. Some have put-or-pay clauses to guarantee volume. A structure of this sort might be tailored for decommissioned photovoltaic module recycling, especially if its infrastructure piggybacks onto that for the electronics industry.

Recycling Hotline for Do-It-Yourselfers

Recycling infrastructure has grown rapidly for used automotive oil filters; 110 recyclers belong to the Filter Manufacturers' Council, many of whom are branches of used oil recycling companies. The Council established a Recycling Hotline (something the decommissioned photovoltaic module industry should consider), and experimented with special programs to induce weekend mechanics and other do-it-yourselfers to make a special trip to bring the filters (and used motor and lubrication oil) to recycling locations. Retailers who accept filters for recycling find that do-it-yourselfers make an extra $13 of purchases per trip. This generation of extra sales associated with campaigns to induce *special* trips to return old decommissioned modules might make retailers more interested in participating in take-back efforts.

Modifying MRFs to Accommodate Decommissioned Modules

The decommissioned photovoltaic module industry might finance additions to existing MRFs to accommodate the dismantlement, sorting, and simple shredding or crushing of decommissioned modules. Automated inspection systems being designed for electronics disassembly may be applicable to decommissioned modules.

CONCLUSION

Many paradigms exist for developing the institutional infrastructure needed to manage end-of-life recycling of decommissioned photovoltaic modules. Of the options explored a combination of the utility (large customers) and battery (photovoltaic industry consortium) models appear to represent near- to mid-term targets of opportunity. However, the lack of an adequate recycling infrastructure, attractive end-markets, and clear economic incentives, present formidable impediments to a self-sustaining recycling system.

REFERENCES

[1] S.J. Reaven et al., "Model Institutional Infrastructures for Recycling of Photovoltaic Modules", BNL Report #62837, January 1996.