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VendEnergy

A Rechargeable Battery vending machine for removing disposable batteries from waste stream.

Figure 1. Battery Vending Machine
Prototype version 1.0

VendEnergy - a rechargeable battery vending machine to remove disposable batteries from the waste stream.

Ideas Final Proposal

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1. Summary

The energy in an alkaline cell costs less than 1 penny by grid prices. With this realization, a distribution model based around leasing cartridges and selling instant energy was envisioned and a vending machine for processing and conditioning rechargeable NiMH batteries was built.

Each year 2 billion batteries are sold in America itself. That equals to about 8 batteries per person annually. Out of these, 350 million are rechargeable batteries. A major chunk of this goes into the land fillings all around the nation marked as solid waste, causing various health hazards.

Our **Idea** is to have a vending machine that would take the batteries in; clean, and recharge them, and vend a recharged battery instantly at a much lower cost than a new physical battery. This comes under a paradigm of what we would call an 'industrial ecosystem' - a network of physical infrastructure that supplies a service whilst digesting its own waste - a network of such battery vending machines negates the need for single use cells. The sales model is one of leasing the hardware cartridge, and paying for the energy.

2. Problem Description and Background

Improperly disposed batteries are one of the major cause of heavy metal contamination in the food chain. For eg. just a few ml of mercury can make thousands of cans of tuna fish toxic. Most alkaline batteries contain mercury. Many rechargeable batteries contain toxic heavy metals like cadmium, Lead and mercury off-course. These batteries when thrown away can cause serious harm to human health and environment when discarded in ordinary household or workplace waste. Approximately 73 percent of municipal solid waste is land filled or incinerated. In land fills, there is a high probability that the heavy metal will leach slowly into the soil, ground water and surface water. When a solid waste is incinerated, the heavy metals can enter the air through

smokestack emissions and can concentrate in the ash produced by combustion. When the incinerator ash is disposed of, the heavy metals in the ash can enter the environment.
Figure 2. total solid waste produced in United States in 2000, with batteries included in the other category (before recycle)

From figure (2) which depicts the total solid waste produced in United States in 2000, with batteries included in the other category (before recycle), one could argue that batteries form a negligible portion of solid waste. To the contrary, though batteries form a very small portion of total solid waste generated in United States, Ni-Cd batteries accounted for **75 percent** of cadmium found in municipal solid waste in 1995. Similarly small lead batteries accounted for **65 percent** of lead found in MSW (Municipal Solid Waste) in 1995. [1]

Once into the environment, these heavy metals make their way into the food chain. This is a very serious consequence. The various possible health effects associated with ingestion of inhalation of heavy metals through water, food, or air include headaches, abdominal discomfort, seizures and comas. Additionally, several heavy metals are known to be carcinogens.

These figures get more astounding in developing countries (urban city) scenario where know-how to recycle and financial support are both missing. This strongly advocates for very stringent policies on disposal of battery waste, in all communities.

Yet humanity depends on the battery as a power source. In the year 2000, the total battery energy consumed globally by laptops and mobile phones alone is estimated to be 2,500MW. This equals 25,000 cars powered by a 100kW engine 134hp) driving at freeway speed. Thus the use of battery as a mobile source of energy will ever increase. Thus we need to find creative ways to tackle with problems which usage of battery causes for environment at large.

2.1 Target Community

Because of the large scale and ubiquitous nature of the problem described above, we decided to start with a close knit community of users, and carefully study acceptance of our solution in that community . Thus we have decided to experimentally put up our vending machines on **MIT campus** itself to see if we can achieve what is described as a "Zero Waste Society". (in reference to battery usage)

2.2 Fact sheet for MIT

Figure 3. Collection site at Media Lab

Following are some general facts which we gathered from discussions with the Environment, Health and Safety Department staff at MIT. They helped us decide key parameters for our solution.

1) MIT offered recycling services starting last spring 2002.
2) Since then 80 pounds of solid waste in form of rechargeable batteries has been processed and sent to RBRC (Rechargeable Batteries Recycling Corporation).
3) Collection mainly from three sites on campus (student dorms currently excluded)
4) A new regulation from Environmental Protection Agency, US allows alkaline batteries to be disposed as solid waste. This lands up at Land filling sites.
5) A large number of community still uses alkaline batteries (cheaper initial purchase cost).
6) MIT pays 1$ per pound for recycling rechargeable batteries
7) A large producer of alkaline disposable batteries is Medical department cause of use of various electrical devices.

3 Our Innovation

Our solution to the problem is to install a network of battery vending machines, which take a rechargeable/alkaline battery from a user and some credit, and return a fully charged rechargeable battery instantly. The user is given some credit for depositing a battery into the system. This acts like an incentive for the consumer to come to the vending machine and not dispose the battery shell anywhere. The machines would be as prevalent as soda machines, around general higher use of alkaline batteries
stores, in book shops, student dorms etc. Thus we would be able to collect almost all of the batteries being dispose and provide a service (providing instant mobile power) to a large community.

The most innovative prospect of our solution lies in providing "**Instant Power**" to the user. Right after a user puts a battery into the vending machine, he receives a fully charged battery. Thus he does not have to wait for his battery to charge and can walk away with a charged battery right away. A quick test on the voltage profile of the battery provides a hint about its usage over a period of time. Thus if a battery can not be recharged further, it is automatically collected into the recycling bin, thus getting the unusable battery out of the solid waste cycle.

Figure 4. Vending machine Prototype 1.0 with a inbuilt credit System.

3.1 Cost of mobile Power

Power obtained through the electrical utility grid is most cost effective. Consumers in industrialized countries pay between $0.05 and 0.15US per kWh. Thus another key feature to note is the cost reduction of mobile power to the consumer. On right Figure 5. is a metric of cost for using different kinds of power batteries, compared to the grid cost. Thus Figure 5 evaluates the cost to generate 1kW of energy. We take into account the initial investment, add the fuel consumption and include the eventual replacement of each system.As can be seen clearly cost of grid power is way below any battery.

Figure 5Cost of generating 1kW of energy.

As is clear above, the vending system forms a closed system. The idea described is analogues to how nature takes care of toxic substances generated in various bio-logical cycles. This is done using closed cycles. The vending machine also describes a closed eco-system where the machine eats away its own waste. Thus the notion goes beyond just "recycling waste " to a much more efficient "Zero Waste Cycle". Since the system also collects all kinds of batteries, it insures a well organized collection cycle amongst a community. Also the user depositing a battery is accordingly credited so that he has an incentive of using the machine over and over again.

4. Prior Art

Prior art can be divided into two sections.

A) Initiatives taken by various organizations towards getting batteries out of the solid waste cycle. These include several federal/state agencies, various NGO's and corporate companies working on recycling programs specific to batteries.
B) Use of commercially available recharging devices for personal use. These include single battery chargers to multiple battery charging devices.
C) Other kind of Recycling machines, like plastic recycle machine.

We would discuss here advantages and Disadvantages in products / options that exist for a common user.

Flow chart for the user interface for the vending machine

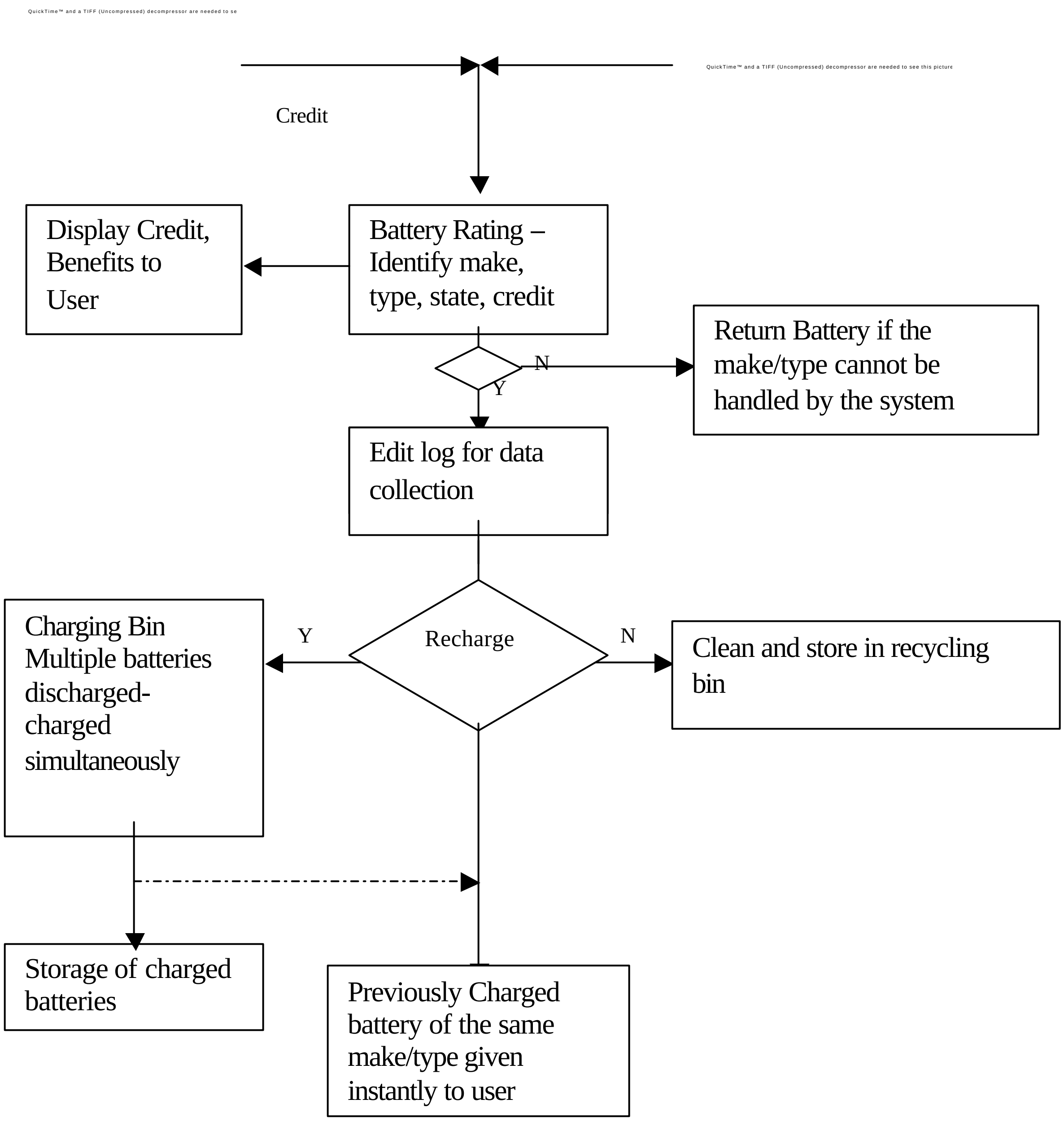


Figure 6 Flow chart for the vending system. The system insures that all rechargeable batteries are cycled through their limits of charging. Also no alkaline/used rechargeable battery escapes into the solid waste cycle.

4.1 Organizations

a**) Multi-stakeholder Initiatives**

Home Depot is partnering with the Rechargeable Battery Recycling Corporation (RBRC), a nonprofit, public service organization dedicated to recycling rechargeable batteries, to integrate

RBRC's recycling program into Home Depot stores throughout the U.S. and Canada. RBRC's program recycles all portable battery chemistries, including those commonly found in cordless power tools (nickel cadmium and nickel metal hydride batteries) and those found in other portable electronics products (lithium ion and small sealed lead batteries). Under the partnership, RBRC has installed battery collection boxes in participating Home Depot stores. Also supporting the partnership are several power tool manufacturers, including DeWALT, Black&Decker, Bosch, Makita, Milwaukee, Porter Cable, Ryobi, and Skil. DeWALT is assisting in the implementation of the RBRC program within Home Depot stores, which includes training Home Depot staff and monitoring collection boxes.
(MSW – US environment protection agency – source)

b) The Mercury-Containing and Rechargeable Battery Management Act
(the "Battery Act"), which was signed into law on May 13, 1996, removed previous barriers to Ni-Cd battery recycling programs resulting from varying individual state laws and regulatory restrictions governing the labeling, collection, recycling, and transportation of these batteries. The Act facilitated and encouraged voluntary industry programs for recycling Ni-Cd batteries, such as RBRC's national Charge Up to Recycle! program. The Act also established national labeling requirements for rechargeable batteries, ordered that rechargeable batteries be easy to remove from consumer
products, and restricted the sale of certain batteries that contain mercury.

B) **Commercially available Recharging devices**

Disadvantages :

1) They are an added cost to the rechargeable battery that a person buys. Since an initial cost for buying a personal recharging could be very high, many users would refrain from using rechargeable batteries. This is highly prominent in developing countries, where any added cost to the consumer is a huge hindrance in the sale of a product.
2) Since almost all the commercially available chargers only charge a specific type, size and shape/make of a battery, thus the user must posses many different kind of chargers with him. Since electronics goods use all kinds of batteries it is highly unlikely that a user will posses all these different chargers.
3) A charger goes through a voltage profile while charging a battery. Thus time of charging varies and can be anything from 15 minutes to 1 or more hours. Since life of a rechargeable battery depends on the battery being fully charged and fully discharged, the user needs to be very patient and allow a full charging cycle for the battery.

Advantages –

1) Wide spread use of charging devices in developed countries.
2) A personal device which can be carried where ever you are traveling.

Fig. 7 An example commercial recharging device

D) Plastic Recycle machine as an example of passive recycling machines. Though these machines do provide a credit to the user who deposits a bottle and also make the recycling simples by cleaning and classifying plastics, they do not add any value to the plastic itself. Comparing it to our vending machines, we do add value to the battery which is recycled, and provide a much needed service of “instant power” to the consumer.

Figure 8 : An example of a plastic recycle machine.

Advantages of our solution as compared to existing systems

- Instant power provided to the user, meeting his needs of mobile power.

- Provides an option to the user of recharging his batteries when away from his home, places like markets, campus, bus stop etc. In a normal case, user goes ahead and buys a new battery in such circumstances.
- Since based on the grid cost, a battery stores only pennies worth of power, it is highly economical to use such vending machines, much provide mobile power for cheap.
- Credit system built in, thus a user has strong incentives to use the system.
- Builds a formal, closed and safe recycling system around battery management system.

5 Implementation

5.1 Technical Description

The machine design can be broken up into four crucial components. Here we also give stages which we have implemented by now.

- Mechanical Design for battery vending system
- Efficient multiple Battery charging unit
- Credit evaluation and basic vending machine controls (built in most vending machines)
- RFID tagging system, to create logs of battery usage in a closed community.

Still to be completed

In functional stage with iterations with multiple iterations

Since batteries come in variety of sizes, makes and voltage specifications. We decided to concentrate on a single type of batteries, currently Nickel Metal Hydride (NIMH)

5.2 Mechanical Design

By now, two working real scale prototypes have been built for the vending machine. The final prototype is currently being built. Here we will describe various details of the old prototypes and progress made in building the third prototype. These prototypes have immensely helped us in realizing the difficulties of designing an assembly line to handle batteries efficiently.

Various issues which pose challenges in the assembly line include

- Orientation of batteries - Since charging units require fixed orientation of a battery, the input module needs to take a battery in a given orientation and rotate/translate it around to give a fixed orientation with low tolerance/ error rate
- Providing feed for many batteries simultaneously. This means, taking a batch of batteries and automatically feeding them in a serial manner.
- Charging unit for many batteries.
- Storage unit.

Following pictures illustrate various prototypes built over a period of time. Complexity of the system currently limits us in the number of batteries we can charge at a given time. They vary from 10 in a smaller prototype to 15 in a life size prototype. We would be increasing this capacity to 30 or more by using multiple discs in the vending machine in the final prototypes. This is crucial since it would be essential to have a high inbuilt capacity to handle higher loads of usage at given times. (The prototype shown below was built with Bret Ridely)

Figure 9 : A user with the prototype machine.

Figure 10 Multiple views of previous prototype ,with a set of NiMH

Figure 11 : Front view of the vending machine with charging ring and support structure

A smaller Lego prototype was also built, with a couple of highly enthusiastic high school students. The students learned how to use the laser cutter, and use crickets for control systems. The prototype built helped a lot in visualizing failure modes for the machine. Here are some details of the mechanisms they used. This is a much smaller prototype and uses Lego components to quickly prototype a working design.

Figure12 : A smaller prototype built out of lego. The machine charges 9 batteries at a time, and does not have a assembly line for multiple batteries. A single battery is taken at a time, and oriented for charging. Crickets (http://llk.media.mit.edu/projects/crickets) have been used as controllers for touch sensors and motor control ers. This provides a very quick way to build the prototype for testing various assembly lines.

Most of these prototypes have been manufactured on a laser cutter and a water jet machine available in the Media Lab. This provides us with a quick way to test our assembly line before putting final versions in CAD. We are currently making the CAD model for the final version.

5.3 Charging modules

The charging module is different from all the commercial modules available since, we need to charge a large number of batteries at a time. This number various from anywhere between 10 to 30. No commercial chargers deal with such a large pack of batteries. Since there are commercial IC's available (MAXIM 712) which provide a current profile necessary for optimally charging NiMH batteries, we need to scale the charger to handle more batteries.

We have been exploring the MAXIM EV charger kit, which is a prototyping kit using MAXIM 712/713 [2] charger chips. This provides serial charging of 8 batteries at maximum.

Figure 13 :MAX712/713 EV Kit (see data sheet)

We have used a couple of such boards to charge batteries in greater number. The kit provides DIP switches to control the number of batteries to charge. Since commercially available IC's (MAXIM) provide a very efficient way of charging batteries, we would initially be going ahead with a commercial system, and in later stages invest time on a more robust charging device.

The issues we have been currently focusing on to improve the charging mechanisms include

- Reducing the contact-ohmic resistance. It requires a lot of force to make a good metal to tip contact on a battery. This introduces a lot of ohmic resistance thus reducing the efficiency of charging cycles.
- Charging profile tuned to the battery being used. Different batteries have different charging profiles. Thus tuning the charge cycle for particular batteries in later versions where we would like to charge different types of batteries together would be a key issue.
- Storage of charged batteries at a low temperature. Since there is a leakage of charge in NiMH batteries if stored for long unused. Thus we would like to reduce the leakage current by storing the batteries at a low temperature.

5.4 Vending machine

We have procured a working vending machine from a lab sponsor. This provides us with a inbuilt credit system, which takes care of the coin collection/counting mechanisms. The controls for the machine are programmable thus making it easy to use as a battery vending machine. Though in final versions we would like to use a smaller size vending machine. See figure.

5.5 RFID data logging system

For study purposes only in initial installations, we would like to log the usage of different types of batteries, how often they are charged etc. Thus the system could function as a data collection device too, providing real usage of the system and popularity of types of batteries in the market. This data could be useful in critically placing the machines and also to battery manufacturing companies in large.

The data logging is done using cheap RF ID chip solutions readily available. One of such systems we are procuring is a ATMEL 125/134 Mhz read/write RF IC's. Thus we can read and write more then 100 bytes of data on these small chips which are attached to the batteries. This provides us with the information when a battery comes back for a recharge again , and can provide crucial usage information. A small antenna and a RFID reader is attached in the machine which is linked to a data logger.

Data Logging is only a test feature and so would be absent in final installations. Thus it does not add to the cost of the total installation. Currently we will be doing data logging on a small DELL desktop computer running linux, which sits inside the machine.

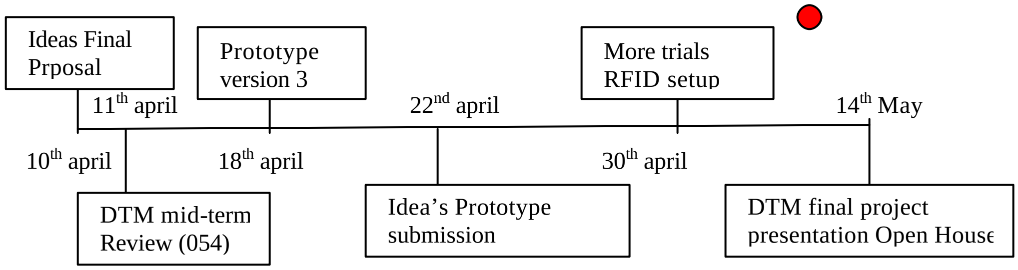
6 Implementation plan.

Sites for proposed Battery Vending Machines , based on regions which produce maximal battery waste on MIT campus

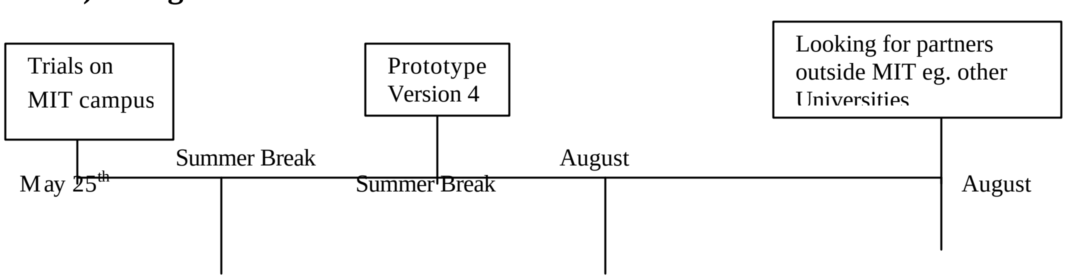
The following sites have been chosen based on high disposal of batteries from these locations on MIT campus

We are planning to work on the following time line

a) Short term plans:



b) Long term Plans



Initial integration with MIT recycle

Permanent installation : Data analysis from logger

Looking for commercial Partner amongst battery manufacturers/recycle companies

7 Current Challenges being faced

- After building a couple of prototypes, it is clear that the battery assembly line needs to be very robust. A jamming fault of one in a thousand could bring the system to a stand still. Thus we have been trying to simplify the complexity in current designs to get a robust design.
- In-corporation of charging of different size/type/make of batteries (other then NiMH batteries as in current design) would be a considerable challenge. Though NiMH has been chosen as a battery of choice since it currently uses lowest amount of toxic compounds. We would need to switch to a system which can handle various kinds of batteries.
- Reducing Ohmic contact resistance for higher efficiency using "Zero pressure clamps", thus providing good electrical contacts to the battery.
- We fear a resistant from battery manufacturing companies in partnering with a product we are proposing. This is cause our system when implemented would reduce number of batteries used per person per year. This maps directly to loss of income for battery manufacturing companies. Thus a need to device a sustainable business model would be crucial.
- Building a network of such machines to be adopted by a community of users. Scaling to an optimal numbers is very crucial for users to believe that the vending machines are widely available at times of need.
- Involving a business student to develop upon the business proposition of the idea. This would involve estimating economics of manufacturing these vending machines and coming up with a credit plan for users, as an incentive for using such facility.

8 Support Network

Currently we are in touch with the following organizations at MIT. Since the idea is to be able to implement a small version of vending machines network on campus, we were very excited with the response from the recycling initiatives at MIT. Also listed is a NGO in the field of recycling rechargeable batteries, which we look forward to get in touch with

1) Justin Adams
   Environment Technologist
   MIT – Environment , Health and Safety Office
   Building N52-496
   77 Massachusetts Avenue

2) Recycle@MIT (Battery handling)
   MIT department of Facilities
   Facilities Administrative Offices

3) MIT Recycling TASK Force
4) SAVE group at MIT
   S.A.V.E. is a group of MIT students dedicated to increasing environmental awareness on our campus and in our community. We gather weekly to discuss environmental problems and their solutions, and to plan actions and

events which will help us realize our goals of living in harmony with the earth.

i) SAVE works cooperatively with our school's administration on recycling and waste reduction, resource conservation, and building design. SAVE meets regularly with them and have been successful in instituting recycling and promoting the use of environmentally friendly products.
ii) SAVE shares knowledge with our peers about environmental problems and about living in harmony with the earth. We do this primarily by hosting events during Earth Week, in mid April. We distribute information, organize lectures and discussions, and hold workshops on reducing environmental impact.
iii) Finally, SAVE networks with students at other universities to share ideas and to work together towards environmental goals.

5) RBRC (Rechargeable Battery Recycling Corporation) :

The Rechargeable Battery Recycling Corporation (RBRC) is a non-profit public service organization dedicated to recycling Nickel Cadmium (Ni-Cd), Nickel Metal Hydride (Ni-MH), Lithium Ion (Li-ion), and Small Sealed Lead *(Pb) rechargeable batteries.

Since 1994, RBRC has recycled more than 20 million pounds of rechargeable batteries. RBRC has also earned numerous awards and recognition, including the Keep America Beautiful First Place National Award in the "Reduce, Reuse, Recycle" category, Leadership Award by the North American Hazardous Materials Management Association, Recycling Council of Ontario Minimization Award, Recycle at Work by US Conference of Mayors, inclusion in Environment Canada EcoAction Network and was named "Environmental Partner of the Year" by The Home Depot in 2002.

Large scale community Impact

1) MIT being such a high profile technical university, we produce a lot of techno-trash. There are no well defined disposal techniques for many kinds of such waste. Such an integrated approach to hazardous waste management would definitely trigger more responsive behavior from the community at large regarding other wastes.
2) This would also increase awareness amongst the community regarding general importance of recycling.
3) There are a genera of closed ecosystems (machines which eat their own waste) which can be worked on similar to the described concept.
4) Since **vendEnergy** is a minimal intervention automated battery handling system, a much more efficient handling would result. Mishandling of many kinds of batteries result in accidents which can thus be avoided.

Team Info and brief Biography

Manu Prakash

Manu has been actively involved with ThinkCycle group from the times of DYD'01 held at MIT and more recently DYD'02 at Banglore, India. He is currently co-teaching the DtM 2003 design studio and seminar course at MIT. He is mentoring a couple of student teams in designing and prototyping DtM projects. In future Manu intends to launch DtM classes at Engineering colleges in India.

A Master's candidate at MIT Media Lab and Media Lab Asia fellow, Manu is fascinated by the notion of Engineering students in developing countries solving large scale community problems.. An alumni from IIT-Kanpur(India), Manu co-founded the BRiCS program intended to introduce Robotics in formal/informal school curriculum in India. Manu's research interests revolve around tools for Micro-system Design.
For VendEnergy, Manu is providing assistance in Electrical/Mechnical design and fabrication for prototypes.

Mike wolf

Breif Biography- Mike is a highly enthusiastic Undergraduate student in DTM'03. He intends to do a major in Physics and Mechanical Engineering. He also works at the Robotics Life group at the Cambrige One Center.

He is working on the mechanical design of the newest version of vending machine. He is also fabricating the new version for the machine in the Media Lab.

Saul Griffith

Brief Biography- Raised in Sydney, Australia, Griffith studied physical metallurgy at the University of New South Wales and then completed a one-year exchange at the University of California at Berkeley in materials science and engineering. After returning to Sydney, Griffith earned his Master of Science in mechanical engineering and materials/recycle fiber composites from the University of Sydney in 1999. He then attended the Massachusetts Institute of Technology where he received his Master of Science in media arts and sciences. Currently attending MIT, Griffith is pursuing a Ph.D. in nanotechnology and micro/ meso fabrication and rapid prototyping

Saul with Brent Ridely initially conceptualized this project. He is providing his expertise in the mechanical design of the newest version.

Brown, Keith A

Brief Biography- Keith is a undergard at MIT, also a student at DTM'03.

He is working on mechanical design and prototyping of the system. Keith is also preparing a credit model for financial sustainability of the project.

Acknowledgements

Bret Ridely – He helped in making and conceptualizing the first prototype of the vending machine. His contributions provides enormous leap to the project.

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www.epa.gov
[2] Maxim charging kit MAX 712/713 EVKIT
Data Sheet www.maxim-ic.com

Some useful web sites.
http://www.inmetco.com/batt.htm
http://www.scrap.org/articles
http://www.recycle.net/battery/index.html
http://www.recyclingtoday.com/