RECYCLING AGRICULTURAL PLASTICS IN NEW YORK STATE

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RECYCLING AGRICULTURAL PLASTICS IN NEW YORK STATE
EXECUTIVE SUMMARY

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Preface. This report is a product of the Cornell "open burning group," which formed in Winter 2002 to assess the extent and environmental health significance of open burning of household wastes and agricultural plastics in New York State (NYS), and begin work towards reducing these practices in order to protect public health and the environment. The report focuses on disposal of agricultural plastics—rather than on the household waste stream—for reasons that include the importance of agriculture in NY and the role of Cornell's College of Agriculture and Life Sciences in working with NYS agriculture and the environment.

Background and rationale. Plastics (LDPE, HDPE, polystyrene resins) have become ubiquitous in agriculture: In dairy farming they are used as silage bags, bunker silo covers, bale wraps and twines; in nurseries and ornamental horticulture they are used as hoophouse covers, trays and containers; in fruit and vegetable production, as row covers and mulch films. Plastic pesticide containers are used in all sectors of agriculture. Increasingly, plastics are substituted for the longer lasting materials previously used in agriculture (*e.g.,* silage bags in place of concrete silos, plastic hoop houses in place of glass green houses) because of production efficiency and economics. More than half the plastics are disposed by burning on-farm, with most of the remainder buried or dumped on-farm. Due to inefficiencies of open combustion, emissions from open burning are much greater per mass of material burned than emissions from controlled incineration (*e.g.,* 20 times as much dioxin, 40 times as much particulate matter). These emissions pose risks to human health.

Objective. This report compiles and evaluates information about recycling agricultural plastics. Its objective is to facilitate development of an infrastructure in NYS for off-farm disposal of plastic wastes, thus avoiding the environmental health effects and other liabilities of burning, burying, or dumping on-farm. Even in the absence of mature recycling markets, such an infrastructure is crucial because a steady stream of quality feedstock is needed in order for re-processing markets to be developed and secured.

Contents. The report identifies *(i)* major uses of plastics on NYS farms, by agricultural sector and type of plastic resin; *(ii)* recycling technologies that are currently viable or that may be realistic in the near future; *(iii)* technical and infrastructural issues, as well as incentives and constraints to greater utilization of recycling technologies; and *(iv)* processes, agencies, and individuals involved in preparation and collection of materials.

Findings.

• The extent of use and the life cycle of agricultural plastics in NYS has not been sufficiently quantified or valued to enable an assessment of the feasibility of recycling or re-processing operations. The economics of plastic use and recycling, as well as farmer incentives and constraints for recycling, should be better understood.

• Recycling of agricultural plastics has lagged behind other plastics recycling because *(i)* agricultural plastics are often of lower quality due to contamination with agricultural debris and degradation by UV light; *(ii)* agricultural plastics are dispersed across the rural landscape, more costly and inefficient to collect than urban plastics; *(iii)* NYS farmers have lacked incentive to recycle because it is legal to burn and dump waste plastics on-farm, and costs for collecting, compacting, and transporting used plastics off-farm for recycling have been higher than costs for on-farm disposal.

• Contamination remains a significant impediment to recycling some agricultural plastics. Research and development are needed for improved processes and equipment to reduce and remove accumulated debris (*e.g.,* by washing, agitation, or chemical action), and for re-processing systems that can better handle plastics contaminated with soil, moisture, pesticides, vegetation, etc.

• The feasibility of regional or statewide recycling programs should be explored, given the capital costs for recycling equipment, sporadic and seasonal plastic removal, dispersed feedstock for recycling, and the need for a critical mass of materials in order to be cost effective and engage the interest of handlers, brokers and re-processors.

• Neighboring states and Canadian Province have (or are developing) successful programs for recycling various agricultural plastic resins. For similar success in NYS, agency or organizational "champions" and a favorable policy climate are recommended, because market economics alone do not provide sufficient incentive to recycle.

• Despite the impediments to recycling agricultural plastics, recycling programs are underway in the Northeast US and Canada for handling most types of plastic resins used in agriculture. *E.g.,* a nationwide, industry-sponsored network for collecting HDPE pesticide containers; an industry-sponsored program based in Ontario, Canada, that picks up, pays for, and re-processes polystyrene nursery flats and trays in the US and Canada; an LDPE nursery film collection program in New Jersey that was opened to out-of-state producers in 2002; a plastic lumber re-processing technology based in Prince Edward Island, Canada, capable of handling "dirty" LDPE plastics used in dairying; and development at Penn State University of a plastic fuel nugget that can be burned for energy recovery.

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PREFACE

This report is a product of the Cornell ad hoc "open burning group," which formed in Winter 2002 to:

- assess the extent and environmental health significance of open burning of household wastes and agricultural plastics in New York State; and
- begin work towards reducing these practices to protect public health and the environment.

The "open burning group" includes Cornell faculty and extension educators with expertise in environmental health and cancer, waste management, risk analysis and communication, combustion science, agriculture, toxicology, and chemical engineering (members are listed in the "Contacts and Resources" section of this report). Our current work on open burning of household and agricultural waste is a continuation and extension of the longstanding interest and prior work of the Cornell Waste Management Institute (CWMI) (*e.g.*, see AWMRS 1996a, b). The ramifications of open burning and its alternatives cut across many areas of community and academic concern—including human health, environmental quality, and community economic vitality and development. Members of the "open burning group" interact on these topics with diverse stakeholders through participation in Cornell Cooperative Extension's *Environmental Health in Agricultural Communities* and *Waste Management* Program Work Teams.

A strong impetus for our current effort was the concern brought to us in 2002 by several New York State citizen groups about adverse health effects from open burning of wastes (these groups include Cancer Action NY, the Otsego County Burn Barrel Education Committee, the Otsego County Conservation Association, the Chenango County Farm Bureau, and the New York Center for Agriculture, Medicine and Health (NYCAMH).

As the "open burning group" surveyed the breadth of topics relating to open burning of wastes and possible strategies for action, we decided to focus initial attention on technical and infrastructural issues and impediments to recycling, rather than on public education about health hazards of burning, or on policies to prohibit burning—reasoning that neither education nor regulation would be well received nor effective in reducing health risk unless better and more environmentally-benign disposal options are available or conceivable. While social factors (*e.g.*, cost of tipping fees, old habits, convenience, etc.) may underlie the choice of on-site or off-site disposal for both farms and households, we believe that clarity about technical issues, options and impediments will better enable us to work around and with social, economic and political barriers to recycling.

We also decided to focus initial attention on agricultural plastic wastes, rather than on the household waste stream, despite the likelihood that New York State households may collectively be burning a larger quantity of materials than are burned in open fires on farms. Our reasons for focusing on agriculture include:

- the role of the Cornell College of Agriculture and Life Sciences (CALS) in working with New York State agriculture and the environment;
- the reality that most households have existing options for off-site disposal and recycling, whereas we did not know the options and impediments for farmers in using these facilities and programs;
- the importance of agriculture in New York State, in terms of commodity value and agri-tourism;
- the trend towards increased use of plastics in many agricultural sectors due to production efficiency and economy, albeit without consideration of full life-cycle costs;
- the interest of the agricultural community in options for off-farm disposal of used plastics, so as to reduce pollution load from on-farm burning or burying waste plastics, and the unsightliness of storing growing quantities of degraded plastics on-farm;

- a relatively discrete set of agricultural plastic products, and of regional suppliers, which helps in the development and implementation of proposals and programs. The products we are referring to include plastic silage and haylage bags, bunker silo covers, bale wraps and twines used in the dairy industry; hoop house covers, trays and containers used in the nursery industry; row covers and mulch films used in fruit and vegetable production; and pesticide containers used in all agricultural sectors; and
- the advantages of established networks and channels of communication with farmers through commodity groups, Cornell Cooperative Extension, Soil and Water Conservation organizations, New York Farm Bureau, New York State Department of Agriculture and Markets (NYSDAM), New York State Department of Environmental Conservation (DEC), etc.

This report is intended as a working document. Its objective is to be a catalyst in facilitating development of an infrastructure for disposing of plastics off-farm—preferably by recycling—rather than burning, burying or dumping the materials on the farm. The premise is that even in the absence of mature recycling markets for agricultural plastics, such an infrastructure is a crucial first step towards better product stewardship.

Acknowledgements. We would like to thank colleagues in Cornell's "open burning group" who framed the discussion that led to this report, with particular thanks to Jean Bonhotal and Ellen Harrison of the Cornell Waste Management Institute (CWMI), who shared insights from previous work on this topic in the mid-1990s; Dr. Suzanne Snedeker, who provided information on health effects of open burning; and Dr. Bette Fisher, who provided information on dioxin emissions. We are indebted to the people involved with various aspects of agricultural plastics recycling who responded to our inquiries and provided the personal communications, photos and written materials that informed this report. We thank them very much. These individuals are cited throughout the paper and are among those listed in the "Contacts and Resources" section. We are grateful to focus group participants who provided insights about use of plastics in various agricultural sectors in New York State. In addition to the members of the "open burning group," they are: small fruit specialist Dr. Marvin Pritts, vegetable crop specialist Dr. Anu Rangarajan, livestock and field crops specialist Keith Waldron, ornamental horticulture, nursery and greenhouse specialists Dr. Jana Lamboy and Dr. George Good. We are grateful to Eric Strong for technical work on graphics and web publication, and to colleagues at Cornell and elsewhere who reviewed earlier drafts of the report: Andy Adams, Arthur Amidon, Jean Bonhotal, Martha Clarvoe, Don Gilbert, Jim Gillett, Ellen Harrison, Karen Kritz, John Roulston, Suzanne Snedeker, Bradd Vickers, and Maureen Weir.

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INTRODUCTION

Why recycle? What's the matter with a bonfire fueled by plastic wastes, or with plowing old mulch or dairy film into a field or onto an out-of-the-way pile? The primary problems are that:

- open burning adds pollutants to the air that pose risks to human health;
- dumping can compromise water quality and future farm operations; and
- random piles of used, partly-degraded plastics are unsightly[1].

Recycling improves environmental quality. Society's long-term economic balance sheet likely benefits as well, with lower costs for health care and environmental remediation. While the economics of agricultural plastics recycling may not be incentive enough to fully motivate farmer participation, the low net farm costs of some of the recycling programs described in this report may provide sufficient incentive in combination with other motivations (*e.g.,* aesthetics, good neighborliness, liability, environmental stewardship).

Health effects from open burning of wastes. Due to inefficiencies of open combustion, emissions per mass of material burned are much greater from open burning than from controlled incineration of municipal solid waste (MSW). Comparative data are highly variable because of differences in burn conditions, the quality of incinerators, data quality and collection methods (Gullett et al. 2001; Lemieux 1997; Yasuhara et al. 2002). A study in the early 1990s showed about 20 times as much dioxin[2], 40 times as much particulate matter and many times more metal emissions from open burning (1994 report to US EPA cited in Lemieux 1997, p2). The differences are widening as higher standards are applied to municipal solid waste incineration. Between 1990-2000 emissions of dioxins and furans decreased about 99% and heavy metals, by more than 90% from 66 large municipal waste combustors (US EPA Office of Air Quality Planning and Standards cited in Environment Reporter. June 28, 2002. 33 (26): 1429).

Dioxins—one of the emissions of greatest concern even in very small quantities—are associated with disruption of multiple endocrine pathways, increased risk for ischemic heart disease, cognitive and motor disabilities, and endometriosis (Dalton et al. 2001; EPA 2000; Rier and Foster 2002; Vreugdenhil et al. 2002). They are also listed as a "known human carcinogen" in the 10th edition of the National Toxicology Program's *Report on Carcinogens* (2002). Emerging research in animals and humans suggests that exposure to dioxins early in life may increase risk of breast cancer (Brown et al. 1998; Fenton et al. 2002; Warner et al. 2002). In addition to the health risks of dioxins, particulate emissions from open burning have been associated with many health effects, including increased risk of stroke (Colburn and Johnson 2003; Yun-Chul Hong et al. 2002). Some health effects are more likely to affect nearby communities, but more distant consumers exposed to these pollutants through the food system are also affected.

Types and quantities of agricultural plastics used and disposed in New York State. Several types of plastic resin are raw materials in the plastic products used on farms, principally low density polyethylene used in films (LDPE and LLDPE, #4 resins); high density polyethylenes used both in rigid containers and in films (HDPE, #2 resins); and polystyrenes used in nursery flats and other products (PS, #6 resins). Plastics are used in dairy farming as silage and haylage bags, bunker silo covers, bale wraps and twines; in nurseries, as hoop house covers (in place of glass greenhouses), trays and containers; in fruit and vegetable production, as row covers and mulch films. Plastic pesticide containers are used in all

1 Burying and dumping wastes on-farm can pollute water and diminish the visual appeal of a tourist destination—a secondary economic role of some New York State farmlands.

2 Dioxins are a family of pollutants including polychlorinated dibenzodioxin and dibenzofuran (PCDD/F). There are 75 PCDD and 135 PCDF congeners (i.e., molecular variations). EPA has assigned toxic equivalency factors (TEFs, sometimes referred to aas TEQs, toxicity equivalency quotients) to 17 of these, ranging from 1.0 to 0.0001 relative to the most toxic of the dioxin group, 2,3,7,8-tetrachloridibenzo(p)dioxin (Garthe 2002b).

agricultural sectors. A decade ago it was estimated that nationwide 66% of agricultural plastics by weight were nursery containers; 5%, pesticide containers; and 30%, various types of films (mulch, fumigation, bale wrap) and irrigation tubing (Amidon 1994, Table 1). Current anecdotal evidence indicates that plastic use in dairy farming has increased considerably since the early 1990s. This is visually evident across the landscape of New York, which is the 3rd leading producer of dairy products in the United States and where milk is the leading agricultural product (NY Ag Stats 2002). Nationwide we estimate that 3%—or 1,678 million lb (761 million kg)—of plastics of the resin types used in agriculture are used in agricultural production[3]. To better understand the environmental health significance of burning agricultural plastics, as well as the market potential for recycling programs in New York State, we attempted to establish—but have not yet arrived at—an educated estimate of plastic use and its rate of increase in various sectors of New York State agriculture[4].

Objectives and contents of this report. The focus of this report is on technical and infrastructural issues related to recycling agricultural plastics. Our objective is to facilitate development of an infrastructure for disposing of plastics off-farm—preferably by recycling—rather than burning, burying or dumping the materials on the farm. The shaded portions of Figure 1 show how topics targeted in this report fit into the larger context of the life cycle of agricultural plastics and the even larger context of open burning of plastics and household wastes. In this report we identify:

- major uses of plastics on New York State farms, by agricultural sector and type of plastic resin;
- technical and infrastructural issues in recycling agricultural plastics at end of useful on-farm life;
- processes, agencies, and individuals involved in preparation and collection of materials;
- recycling technologies that are currently viable or that may be realistic in the near future;
- incentives and constraints to greater utilization of recycling technologies for agricultural plastics.

Review of the literature. People familiar with the field of plastics recycling might wonder why we initiated this research, given that the American Plastics Council published the excellent *Plastic Film Recovery Guide* in 1999. The answer is two-fold: (1) agricultural plastics—with their unique characteristics of use, collection and disposal—are not covered in the *Guide*, and (2) the *Guide* surveys only plastic films[5], not plastic containers and other plastics used in agriculture. This report is also not redundant with the 1994 study *Use and Disposal of Plastics in Agriculture*, prepared by Amidon Recycling for the American Plastic Council. That report is a national survey, whereas we focus on recycling in New York State. Also, in this rapidly changing field, decade-old information may no longer be current.

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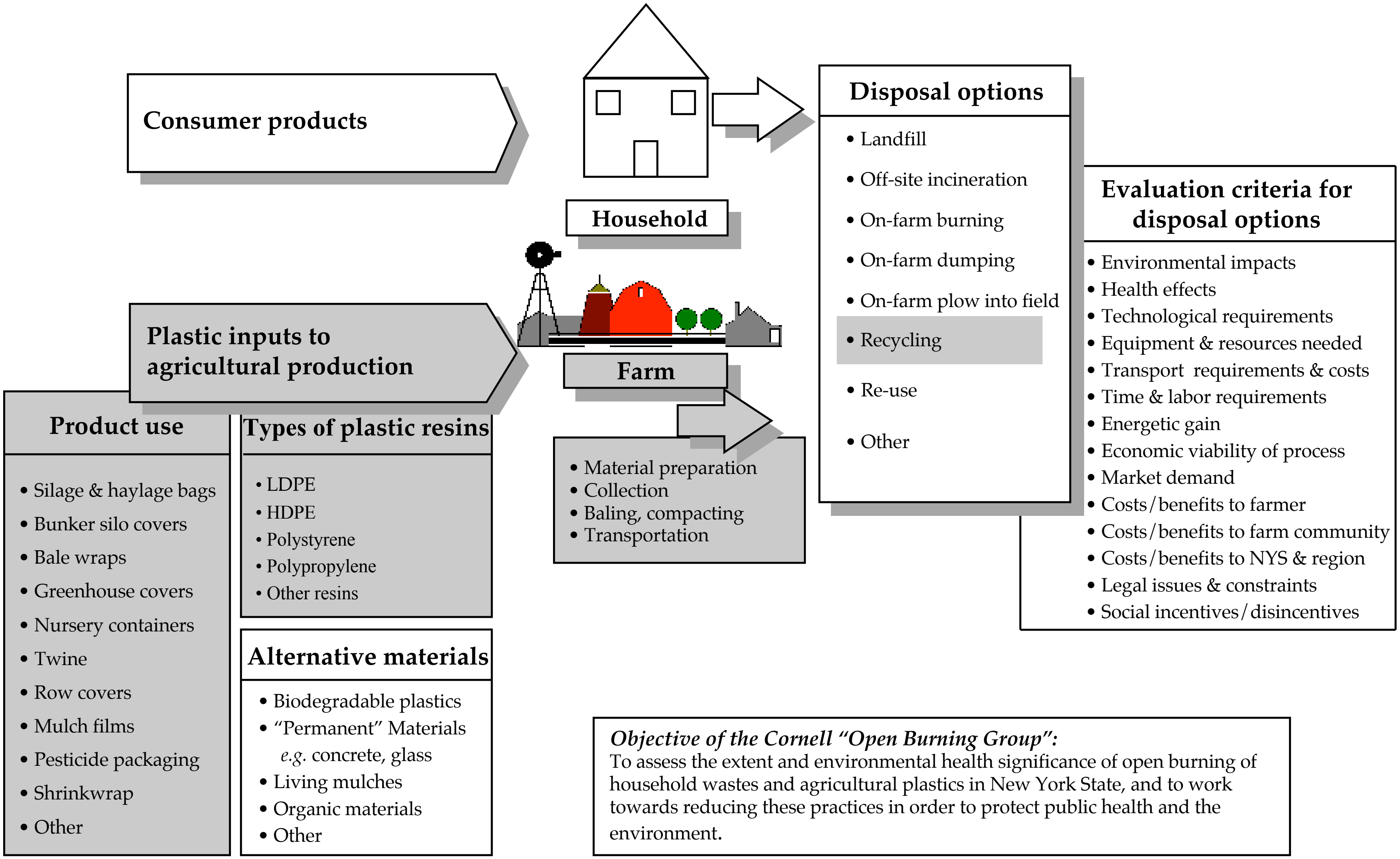
[3] Estimates range from 1-4% of the types of plastics used in agriculture: Amidon (1994) estimates that 521 million lb of plastics were used in US agriculture in 1992, which =1% by weight of the five primary types of plastic used in 2002; the Wageningen Agricultural University's Department of Agrotechnology and Food Sciences estimates that 2% of all European plastics were used in agriculture in 1996 (http://www.ftns.wau.nl/agridata/PlastStats.htm), which is about 4% of the subset of plastic types used in agriculture; and Garthe and Kowal (undated) estimate in the late 1990s that 3.6% of LDPE plastics are used in agriculture. Based on these estimates, on our observation that agricultural plastic use has increased in the past decade, and on an American Plastics Council (2001) graph showing a 20% increase in plastic use 1996-2001, we estimate that 3% of the 55,942 million lb of plastics of the types used in agriculture were used in agriculture in 2002; i.e., 1,678 million lb. (761 million kg).

[4] To develop this estimate we held a focus group with experts in various sectors of New York State agriculture, and developed a survey asking farmers about their use of agricultural plastics and interest in recycling agricultural plastics (see Figure 3). Additional research is needed to verify, elaborate and quantify the qualitative data collected.

[5] Sixty-eight percent of plastic films are made are made from low density (LDPE) or linear low density (LLDPE) polyethylene resins (number 4 resins). High density polyethylene (HDPE) resins (number 4) are also commonly used. Less commonly, polypropylene (PP) (number 6), polyvinyl-chloride (PVC), and nylon resins are also used. Mixed resin films are becoming more common for applications where the performance attributes of different resins is desired (APC 1999, pp28-29).

FIGURE 1. SCHEMATIC OF THE ISSUE: BURNING AGRICULTURAL PLASTICS & HOUSEHOLD WASTE
Shaded sections indicate topics covered in this report in the context of the broader issue



Recycling Plastic Resins used in Agriculture

The development of recycling options for agricultural plastics has been difficult and slow for reasons that can be summarized as *unstable markets, dispersed sources, dirty materials* and *lack of incentive.*

- **Unstable markets.** The entire plastics recycling industry is still immature, with unstable markets and market economies, and rapid turnover in companies and terms of trade. It ebbs and flows in a complex reflection of the dynamics of the larger economy. Buyers in this market are typically independent companies seeking large and steady supplies of the least costly and highest quality materials. In comparison with many other sources of used plastic, agricultural plastics are typically available only seasonally, in relatively poorer condition and small quantities[6].
- **Dispersed sources.** In contrast with urban suppliers of recyclable materials, agricultural sources are dispersed across the rural landscape. Collection of materials is more difficult to coordinate and more expensive to carry out. Reaching a critical volume often requires a large collection area, involving multiple political jurisdictions as well as an efficient collection infrastructure.
- **Dirty materials.** Unlike the soda and milk bottles generated by households, and the shrink wrap and other packaging from industrial sources, agricultural plastics are often contaminated by up to 50% of weight by dirt and debris, vegetative matter, pesticide residue, Ultra-violet (UV) protectants, pathogens and moisture (Amidon 1994). Avoiding such contamination, or removing it after the fact, is costly in time and energy. Recyclable glass and metals do not face similar constraints due to contamination because in the re-processing of those materials contaminants are destroyed by high temperatures. Plastics, however, are processed at lower temperatures that do not remove contaminants. Contaminated plastics are not accepted for most recycling processes, and special processes are needed to handle most agricultural plastics. In addition, because of use outdoors, agricultural plastics may be partially degraded by UV light, rendering them unacceptable as re-processing feedstock.
- **Lack of incentives.** The costs to a farmer for collecting, compressing, transporting and processing used plastics off-farm (so they can be recycled, re-used or landfilled) have been higher than costs for burning, burying or dumping on the farm. Without legislation prohibiting these practices and without social subsidies for recycling (*e.g.,* collection and processing paid by product manufacturers), there has been little incentive for farmers to consider environmental health impacts in selecting the means of disposal.

For all of these reasons it should come as no surprise that 60% of farmers surveyed in Pennsylvania usually burn their used plastics on-farm (Garthe and Kowal) or that a 1996 New York survey indicated that most of the other plastic is buried or dumped on-farm (AWMRS 1996 a, b). A decade ago Amidon estimated that less than 5% of agricultural plastics were recycled nationwide, with a similar percentage incinerated for energy recovery (1994). In the following sections of this report we describe on-farm uses of materials made from several types of plastic resins (LDPEs or low density polyethylenes, HDPEs or high density polyethylenes, and PS or polystyrenes); what is required to prepare these materials for collection for recycling; collection processes; and recycling options (Figure 2).

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6 As examples of the fragility of the recycling market, New York City suspended plastic and metal recycling in summer 2002 due to cost, and is able to resume it in July 2003 because a small New Jersey company is offering $5.15/ton for recyclables rather than—as had been the prior arrangement with other companies—charging nearly $70/ton on top of the City's cost for material collection. New York City is a major supplier of recyclables, generating about 100,000 tons of plastic and metal recyclables/year, yet appears not to be driving the market (New York Times, Jan 14, 2003). We also learned that the market for recyclables disappeared after September 11, 2001 because brokers and processors were overwhelmed by handling debris removed from the area of the World Trade Center. Thus, clearly, the recycling market is driven by factors much larger than agriculture recycling.

FIGURE 2. LIFE CYCLE OPTIONS FOR AGRICULTURAL PLASTICS, BY RESIN TYPE & ON-FARM USE

LOW DENSITY POLYETHYLENE (LDPE & LLDPE) (#4 resins)

(see pages 6-12)

Properties: flexible, lightweight films; compressible foams

Cleaner
- **Shrinkwrap**
- **Greenhouse film**
- **Nursery film**
- **Mulch film**
- **Bunker silo cover**
- **Bale wrap**
- **Silage & haylage bags**

Dirtier

Material preparation
- clean as possible
- baled or loosely compacted

Collection
- NJ nursery film collection program
- drop-off or pick-up by re-processor

Recycling processes & markets
- clean materials suitable for many processes
- "dirtier" plastics suitable for energy recovery & some plastic lumber processes

HIGH DENSITY POLYETHYLENE (HDPE) (#2 resins)

(see pages 13-16)

Properties: rigid containers; opaque, crinkly films; resistant to chemicals.

Pesticide containers
Nursery pots

Material preparation
- empty
- clean, dry
- caps, metal handles, etc. removed

Collection

Ag Container Recycling Council (ACRC) contractors grind, bag, label granulated materials & truck to re-processors

Recycling processes & markets

re-use as new pesticide containers, marine piling, field drain pipe, speed bumps, sub-flooring, plastic lumber & for energy recovery, etc.

POLYSTYRENE (PS) (#6 resins)

(see page 17)

Properties: non-compressible, rigid foams; rigid, insulating materials.

Nursery trays and flats

Material preparation
- residues removed
- palletized
- shrink-wrapped

Collection

full truckloads picked-up by Canadian Polystyrene Recycling Association

Recycling processes & markets
- "closed loop" recycling into new trays and flats
- reprocessable repeatedly into many products

POLYPROPYLENE (PP) (#5 resins)

Properties: lowest density thermoplastic; woven sheets, tarps, sacks

Nursery pots
Row covers
Woven tarps, sacks

Material preparation

many nursery pots are made from processed mixed resins & cannot be recycled again

Recycling processes & markets

end markets and collection intermediary have not been identified

LOW DENSITY POLYETHYLENE (LDPE) PLASTIC FILMS (#4 RESINS)

On-farm uses of LDPE plastics. Low density polyethylene is used to make flexible, lightweight films and compressible foams. Most of the plastic films used in agriculture are produced from LDPE resins. The shrink wrap around pallets of farm supplies may be linear low density polyethylene (LLDPE) films that are produced from the same #4 resin using a lower pressure process (APC 1999, pp28-31). LDPE plastics are the flexible films used as hay and silage bale wrap in livestock operations; mulch and fumigation films on vegetable fields; and hoop house covers in nurseries and greenhouse production. With a surge in use on dairy farms during the 1990s, LDPE plastics have emerged with the biggest share of the agricultural plastics market (Figure 2) (Garthe and Kowal). LDPE plastics substitute for longer lasting materials previously used because of increased production efficiency (*e.g.*, they result in better feed quality and reduce spoilage) and economy.

Despite higher costs over time, disposable, lightweight and portable plastics are often preferred to longer lasting structures, especially by small-scale producers who are thus able to avoid large capital investments (discussion at Cooperstown meeting, Senator Seward office, Jan 23, 2003). In addition, if production is uncertain beyond a seven-year time horizon, then plastic silage bags costing approximately $100 for 100 feet are a more economical option than constructing a bunker silo or vertical silo (AWMRS 1996a). An average New England dairy farm with 100 head is likely to use one or two silage bags per year, each 8-12 feet in diameter and 100-250 feet long (Amidon 1994), *i.e.*, costing $100-$500.

Material preparation for recycling. Ideally, plastics bound for recycling are clean, dry, compacted and amassed at a central collection site. However, for the most part, agricultural plastics are dispersed on farms and fields, and often dirtier than plastics used for non-agricultural purposes. Material preparation involves (a) removing plastics from the field in a manner that prevents additional accumulation of debris; (b) collecting and compacting for transport off-farm; and (c) transporting to a central location. The following discussion first addresses removal and compaction issues, then separately discusses recycling options for cleaner LDPEs and dirtier products. Where materials fall on the continuum between "cleaner" and "dirtier" LDPE film depends both on how they have been used and how they are collected and stored. Relatively clean agricultural LDPE films have much the same array of recycling options as non-agricultural plastics, whereas dirtier materials (*e.g.*, haylage wrap) have heretofore typically been unacceptable for recycling.

When possible, plastics should be collected when dry—since moist films act as a magnet for contaminants—and stored away from UV light, moisture and additional dirt. Speaking in various forums[7], agricultural producers have suggested several scenarios for on-farm collection and storage that could minimize contamination and expense. For example:

- Using hay wagons for temporary storage of plastic films in the off-season, and periodically transporting recyclables to regional transfer stations in these wagons or in stock trucks;
- Backhauling—*i.e.*, transporting recyclable plastics to transfer stations in the delivery trucks used to bring supplies to the farm;
- When animals are fed in a central feeding site on the farm, collecting bale wraps at that site and keeping under cover until transported off-farm;
- Hanging sheets of muddy silage wrap on spikes on an exterior barn wall, allowing wind and rain to help in the cleaning process[8].

[7] These comments were made during discussion at New York State Senator James Seward's office, Cooperstown, New York, Jan 23, 2003 and in personal communications with Jean Bonhotal, summer 2002.

[8] Collecting silage bags from the field in the winter is at best difficult and unpleasant, so they are typically left there until springtime, by which time they are likely to be very muddy or partly degraded.

Even when relatively clean, loose plastic film is difficult to manage and transport. Therefore, plastics are often baled for ease of handling or as a requirement of sale. However, for some recycling processes, more loosely compacted materials are preferred. For example, densely packed bales can create equipment-damaging "hotspots" in incinerators used for energy recovery (Garthe 2002) and difficulties in removing bale ties or wires can be an impediment to efficient handling by re-processors (O'Neill 2002). However, should baling be preferred, there have been significant recent developments in baling equipment.

Baling equipment for agricultural plastic films. The American Plastic Council's *Plastic Film Recovery Guide* describes several types of balers, noting that specialized baling equipment is generally not required for plastic films, although the balers must have certain characteristics to accommodate plastics (APC 1999, pp 17-21, 26-27)[9]. However, equipment used on farms for baling crops is both unsafe to use for baling plastics, and produces bales that are not acceptable for marketing purposes (Garthe and McCoy). Although the *Plastic Film Recovery Guide* describes several "alternative" balers for niche uses, it does not address the unique requirements of agriculture in baling plastics. For agricultural uses a baler should be (a) portable, (b) capable of operating in the field without electricity, and (c) mechanically and logistically capable of handling plastic feedstock as it is removed from the field or from hoop houses, avoiding additional contamination with dirt and debris during the collection process.

Equipment that meets these criteria has been "reinvented" several times, *e.g.*, retrofitted from machinery developed to roll large plastic sheets onto hoop houses (Amidon 1994). One product—the Tiger Baler—was expressly developed for agricultural purposes (initially to remove mulch film from vegetable crops in Florida) and continues to be modified for other agricultural situations. Depending on the particular model of equipment used, the bales formed are 600-650 lb (Tiger Baler website). In personal communications, the designer of the Tiger Baler described how he has used it "for low density films of all sizes and gauges up to 48' wide and 6 mils thick," noting that "the baler was slower with the large size and thick gauge" but that "dirt, moisture and other foreign matter [did] not inhibit performance" (personal communications, Dennis Sutton, Aug 26-28, 2002).

Promotional materials claim that three people can bale 25 or more acres in a day using the Tiger Baler (website accessed Dec 2002)[10]. An independent study of plastic removal from greenhouses determined that five people could remove plastic from six 300' hoop houses per hour using the Tiger Baler. The plastic bales are tied with strips of the same plastic, and palletized for transport on a flatbed trailer. Based on an accounting from a nursery[11] using an early production model, a mobile Tiger Baler unit saved 50-90% in costs of removing plastic covers from hoop houses (CGGA 2001). The mobility of the baler is key

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[9] *E.g.*, the *Guide* notes that some balers are better adapted to dealing with the unique characteristics of plastic and therefore can better meet requirements of plastic recyclers. For example, balers should be set to compact materials to a bale density of 12-15 lb/cu', both to ensure structural integrity to the bale and for transportation cost efficiency. The baler also must be able to counteract the tendency of plastics to "bounce back," which prevents fully filling the bale to the proper density. In downstroke balers, *e.g.*, the type typically used to compact corrugated cardboard, this tendency can be offset by using a full penetration ram cycle, rather than a partial penetration cycle. Because of the greater "bounce back" pressure exerted by plastic against the baler and baling ties, the size of the plastic bale may need to be smaller (approximately 900-1200 lb) than the bales produced by horizontal balers, which are typically more than one ton. Downstroke balers cost in the range of $10,000-$15,000 for a new 60" baler (with used balers selling for about half as much), while the much larger horizontal balers found in commercial recovery facilities cost $30,000 - $200,000.

[10] Presumably similar efficiencies could be realized with other baling equipment designed for this niche market, but we make reference to the Tiger Baler because research data have been compiled using this brand. Mention of this brand name should not be construed as product endorsement by the Cornell "open burning group" nor by the authors of this report. However, the Tiger Baler is recommended in the recent *Connecticut Agricultural Plastics Feasibility Study* that was commissioned by a coalition of nursery greenhouse and florist association members, led by the newly formed Connecticut Agricultural and Business Cluster (CAB) (Amidon 2002; CGGA 2001; FWM 2002).

[11] The Robert Baker Companies in West Suffield, Connecticut, reported in CGGA 2001.

to this cost savings, which would not be realized if the plastic had to be transported to a near-by (*e.g.*, an on-farm shed) or more distant (*e.g.*, a regional processing facility) site for baling (personal communications, Arthur Amidon, Feb 23, 2003).

Without a baler, removal of hoophouse plastic had previously required a crew of 25-30 to cut film into sections, bundle it, and transport it to a compacting dumpster. Due to air trapped during compaction, a dumpster costing $400-$500 can handle only 1000-2000 lb (*i.e.*, the quantity in 1.5-3.0 bales produced by a Tiger Baler). Amidon (2002) calculated that it cost Connecticut growers $0.10-$0.50 per pound to remove plastic without a baler, and up to $0.45 per pound for trucking and tipping fees to dispose of it.

Equipment costs are in the range of $25,000-$35,000 for a Tiger Baler. The collection process also requires a pickup truck to transport the baler, and a tractor for pulling it in the field. An 80 hp tractor is needed to pull the less expensive Tiger Baler or a 40-50 hp tractor is needed for the more expensive model, which includes an independent diesel engine. The baler is sufficiently lightweight to be towed by a pickup truck between farms for on-site plastic removal and baling. Given the relatively high capital investment[12] for occasional use of the baler, the Connecticut *Feasibility Study* recommends formation of a statewide industry recycling cooperative. Whether organized as an industry cooperative or in some other form, our research also indicates the sensibility of a regional operation, with ownership perhaps residing in the private sector, in a municipal solid waste authority, or the Federation of New York State's solid waste management organizations.

New Jersey collection program for "clean" nursery and greenhouse films. Since 1997 New Jersey has organized an annual nursery and greenhouse film recycling collection program under the auspices of the New Jersey Department of Agriculture's (NJDA) Agribusiness Development agency. Agribusiness Development representative Karen Kritz developed the program and facilitates collection of materials. She has worked in conjunction with Dennis DeMatte, recycling coordinator at the Cumberland County Improvement Authority, who interfaces with brokers and re-processing companies to arrange for marketing. The program has operated primarily with in-kind agency funding covering staff time, plus $25,000 from the New Jersey Department of Environmental Protection (NJ DEP), which covered operating costs for the period 1998-2001.

In 2002, collection sites were set up in Cumberland and Burlington Counties—at a solid waste complex, an occupational training center and at East Coast Recycling Associates. Two collection sites will be used in 2003. Arrangements have been made with the NJ DEP Bureau of Hazardous Waste to waive usual permitting requirements for transport vehicles. In 2002—for the first time—the program accepted clean agricultural film[13] from out-of-state growers, becoming the first multi-state nursery and film recycling program in the nation, and thus providing a recycling option for New York State growers.

A spokesperson for the New Jersey Nursery and Landscape Association reports that in the first five years of the recycling collection program, 100-125 growers were involved and that about one-third of the estimated one million lb of nursery film generated annually in New Jersey was recycled through the program, a total of almost 1.8 million lb[14]. By opening the collection to other states in 2002, it was expected that 10-15% additional would be collected. However, the 238 tons collected for recycling in

[12] About 2.5 times the cost of a generic downstroke baler.

[13] Defined for this purpose as LDPE film free of debris—including dirt, weeds, stones, lathing, staples, saran, mulch and stretch film—and bundled and tied with nursery film material.

[14] After seven years of operation, 2.4 million lb have been recycled through the New Jersey program (personal communication, Karen Kritz, Feb 18, 2003). This is still about one-third of the total, if New Jersey nurseries continue to use one million lb/year.

2002 was a 24% increase over the previous year[15] and the largest quantity handled since the program began in 1997.

Experience has shown that New Jersey farmers will travel up to 45 minutes to deliver recyclable film and will pay the $10-$20 per ton tipping fee for recyclables. This fee is substantially less that the $60 per ton landfill tipping fee[16] and, as such, is an incentive for grower participation. Another considerable incentive is New Jersey legislation prohibiting open burning. In comparison, the New Jersey coordinator relayed information from a Pennsylvania survey indicating that growers there—where open burning is legal—would not travel more than 20 minutes to a recycling facility (NJDA 2002a, 2002b; NJFRP 2002; personal communication, Karen Kritz, NJDA, Sept 4, 2002 and Feb 18, 2003).

Recycling options for "cleaner" LDPE agricultural plastics. Recycling options for relatively clean agricultural plastics are comparable to those for other (non-agricultural) LDPEs, and are similarly affected by the vicissitudes of the recycling market. Recycling companies have been listed in several publications (*e.g.*, Amidon 1994; APC 1999; AWMRS 1996b; Garthe and McCoy), but the authors have communicated to us that the information becomes almost immediately out-of-date and is, therefore, of dubious value to commit to print. Companies or groups considering recycling on a commercial scale should contact potential buyers to inquire about current terms for accepting recyclable materials, and perhaps utilize the American Plastics Council's online *Recycled Plastic Products and Markets Databases* of more than 1,700 businesses handling and reclaiming post-consumer plastics (http://www.plasticsresource.com/databases/index.html) (APC online).

Recycling options for "dirtier" LDPE agricultural plastics: mulch film, bunker silo covers, bale wrap and silage bags. The viability of recycling processes for "dirty" LPDE plastics is constrained by the cost, environmental pollution, and/or equipment limitations in dealing with plastics contaminated with normal field dirt and debris—the vegetation, soil particles and moisture that can account for as much as 50% of the weight of collected plastic. We learned about two options: (a) energy recovery (*i.e.*, using plastics as supplemental boiler fuel) and (b) processing into plastic lumber. While viable, technical issues for both are still being resolved.

Energy recovery. In the early 1990s, less than 5% of agricultural plastics were incinerated for energy recovery (Amidon 1994). While there are still impediments to overcome, controlled incineration to recover energy from waste materials may evolve as a relatively cost-effective and environmentally-sound means to dispose of dirty plastics, an option that is preferable to on-farm disposal and—in the opinion of some—also preferable to landfilling[17].

Because densely compacted plastic bales can cause equipment-damaging "hot spots" in incinerators, and because loose plastic films are difficult to handle and dangerous near fire, Penn State University has been working since 1995 on a "densification process" to produce fuel nuggets that could be co-fired with coal in community and agricultural boilers. The intent is that any type of dirty plastics—both film and rigid thermoplastics—can be used as feedstock for the fuel nuggets. The Penn State research group has been working with a cement producer and a mulch film producer, experimentally using the nuggets to generate steam.

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[15] It is not clear from our sources how much of this increase is attributed to out-of-state participation.

[16] When the New Jersey program was started in 1997, landfill tipping fees were more than $100 per ton. Litigation has driven the fees down to $60 per ton.

[17] As noted in the Introduction, pollutant emissions from controlled incineration are much less than from open burning and differences in emission levels between the two are widening. Most reduction in MSW incinerations have been since 1995, when maximum achievable control technology (MCT) standards were put in place (US EPA Office of Air Quality Planning and Standards cited in *Environment Reporter*. June 28, 2002. 33 (26): 1429).

While the "bugs" have been worked out of the production process, investigation and improvement of combustion efficiency are still ongoing[18]. A recently completed round of combustion efficiency tests, performed by the Pennsylvania State University Energy Institute for the National Watermelon Promotion Board, showed that nugget composition varies greatly with the type and extent of inorganic contaminants (14-48% ash by weight), and that the type and quantity of emissions is greatly affected by contaminant characteristics. The more highly contaminated plastics result in more toxic emissions, perhaps because the dirt and debris limit air movement to the combustible materials—a problem that increases when mulches are collected wet. Emissions from some of the experimentally-combusted nuggets exceeded regulatory limits (Garthe 2002b; personal communication, James Garthe, August 2002).

However, it could be expected that the plastic nuggets would be a very tiny percentage of the total mix in a large industry or municipal incinerator. For this reason, and also because high standards for emissions are enforced at municipal or industry facilities, incinerating at these regulated facilities would likely be more environmentally benign than incinerating the nuggets in small-scale burners on-farms.

Plastic lumber. In its year 2000 annual report, the Plastic Lumber Trade Association noted that recycled plastic lumber (RPL) "is leaving the early business cycles of emerging technology and growth and entering into more mature business cycles of growth and market acceptance." The report goes on to describe several of the competing technologies and resin systems on the market, none of which claim to utilize re-processed agricultural plastics[19]. While sales volume of RPL is hard to project—since most manufacturers are privately held or divisions of larger companies—estimated gross revenues are approximately $70-$90 million and growing[20]. The largest market segments are commercial and

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[18] Testing was on LDPE plastic mulch film and irrigation tubing used in production of watermelons and collected from growers in California, Pennsylvania and Florida after crop harvest. Samples were contaminated with mud, sand, clay and plant materials, per realistic field conditions. A "traveling-grate stoker simulator"—simulating a combustion unit typical of those found in coal-fired community and agricultural boilers—was used for testing. Three types of fuel nugget were compared in combustion tests: (a) 100% coal fuel, using a highly volatile coal from the Middle Kittanning seam in PA, (b) 5% plastic nuggets blended with the coal and (c) 10% plastic nuggets. Ash content of the nuggets varied from 14-48% by weight. Chlorine content of the plastics was nearly double that of the coal (2500-2800 ppm of the plastics as compared with 1538 ppm of coal). Flue gas from the stoker simulator was sampled, per EPA test prototcol, for CO_2, CO, SO_2, NO_x, O_2, polycyclic dibenzofurans (PCDD/Fs) toxic equivalent emissions (dioxinTEQs). Although results varied considerably, SO_2 and NO_x emissions from the blends were similar to the 100% coal. Additional studies are planned, including studies with a different type of stoker and different mixes of plastic (Garthe 2002b).

[19] The RPL systems described in the "state of the industry" report are:
(1) single polymer systems producing extrusion foams made from HDPE plastics and used for decking;
(2) extrusion flow molding systems producing railroad ties, and other "thicker" products;
(3) fiberglass-reinforced RPL, which was used to construct a multi-level starting platform at the Lake Placid, New York, luge and bobsled run;
(4) polyethylene and polystyrene resin systems with stronger physical properties than chopped fiberglass competitive products, used for railroad ties, etc;
(5) PVC-based decking;
(6) wood-filled and thermal-plastic systems, such as Trex, which do not meet the ASTM definition for plastic lumber because of their large wood component.

[20] This figure does not include revenues of the Trex Company, which—at nearly $100 million in 2000—are greater than the RPL industry sales as a whole. Trex is not included in industry figures because (as noted in the previous footnote) the mix of waste wood and plastics in Trex products do not meet the American Society for Testing and Materials (ASTM) definition for plastic lumber.

Trex Decking is manufactured from a combination of used stretch film and waste wood, at facilities located in Winchester, Virginia, and Fernley, Nevada. The Trex Company pays freight and $60 - $120 per ton for full truckloads (~40,000 lb) of baled, used PE film. Prices are based upon the type of material and monthly quantities (Trex website, http://www.trex.com, accessed Dec 2002).

residential decking and the park and recreation market—each with about one-third (PLTA 2000). Thus RPL manufacturers are an important market for clean, used plastics of the type described elsewhere in this report. Plastic lumber is included here, among options for "dirty" agricultural plastics, solely because of one company that claims to have developed a unique process for recycling silage wrap and other of the "dirtier" agricultural plastics.

Agri-Plas Systems 2000 Inc. is a Canadian company based in Prince Edward Island (PEI) that developed a technology for re-processing contaminated, "dirty" agricultural plastics. With financial assistance from the Canadian adaptation and rural development fund (CARD) and other sources, Agri-Plas first licensed its technology in 1997 to Island Plastics, a manufacturer of RPL on PEI. Subsequently the technology has been internationally licensed, and negotiations are currently underway to develop facilities in nearby Springhill, Nova Scotia (late 2002), in the New England region of the United States (2004), and at several sites in Europe (sources of information about Agri-Plas Systems 2000 and Island Plastics: AAFC; Agri-Plas b-e; O'Neill 2002; personal communications with Austin Boyd, Agri-Plas CEO, and Andy Adams, Island Plastics, Summer 2002 - Feb2003).

Because of the confidential licensing agreement, we know little about the technical process, how it is differentiated from other methods for re-processing LDPEs into RPL, and why it can accommodate "dirty" plastics when the other technologies cannot. In the late 1990s, the basic "turn-key" Agri-Plas manufacturing system, capable of processing 2,000 ton per year, sold for approximately one million dollars Canadian, including equipment, "recipes" and the training to use them. With additional equipment, the system can easily be expanded to process larger quantities.

A plant of this size operates at capacity re-processing bale wrap generated from feed for approximately 300,000 cows in PEI (or 600,000 cows in New York and New England, where less plastic wrap appears to be used per cow)[21]. To put these figures into a context, New York State farms had an average of 622,000 milk cows 2001-2002 (NY Ag Stats 2002, p35).

Although none of the Trex promotional materials mention agricultural plastics, nor interest or ability to handle "dirty" plastics, in personal communications company representatives indicated (a) that they accept greenhouse film if not too dusty and (b) that they are planning to build a washing facility in 2003. The latter may indicate a potential outlet for "dirtier" agricultural plastics (personal communications with Ana Barros and Martha Clarvoe, summer 2002). Trex is not alone in producing faux lumber from a mix of recycled plastics and waste wood. Other companies are doing so also and new products are in the research and development pipeline, including a micro-cellular foaming of wood and thermal plastic composites under development at University of Toronto (PLTA 2000).

[21] This estimate is based on the simplifying assumption that bale and silage wrap are the only recyclable plastic feedstock used by the plant. It also assumes—per calculations below that are derived from information from several sources about herd size and bale wrap purchases—15 lb of plastic wrap is used per cow per year in PEI and 7.5 lb is used in New York and New England. The difference in quantity between PEI and the Northeast US may be due to real differences in agronomic practice—observers have noted that more feed appears to be wrapped in plastic in Canada than in New York and New England—or may be due to the artifact of different assumptions underlying the following calculations of plastic bale wrap used per cow.

At 2,000 ton per year recycling capacity (=4,000,000 lb) and 15 lb of plastic generated per head per year, the plastic lumber recycling plant would be kept at capacity with inputs from feed wrap from 267,000 cows. If the 2,000-ton plant capacity is measured in metric tons (1 metric ton = 1.102 short tons or 2,204 lb), then plant capacity is 4,410,000 lb of agricultural plastics per year, and the plant is kept at capacity with inputs from 294,000 head of cattle. Using the lower figure of 7.5 lb per cow per year, which is more consistent with the several US estimates, a plant would be kept at capacity with inputs from feed for 533,000-588,000 cows (depending upon whether the plant capacity is given in metric or short tons). For comparison, there were an average of 622,000 milk cows on New York State farms 2001-2002 (NY Ag Stats 2002, p35). Plastic per cow quantities are derived from the following scenarios:

(1) New York State dairy farmer Jim Mumford purchases 24 boxes of plastic wrap for silage bags of dimension 4' x 150', each weighing 40 lb, and one large silage bag of dimension 9' x 150', which he estimates weighs 200-300 lb.

Island Plastics has had a steady stream of feedstock for re-processing, perhaps because on-farm burning of used silage wrap and other plastics is prohibited by the Air Quality regulations under PEI Environmental Protection Act. Burial or dumping on farm is likewise prohibited by regulations requiring permits to operate dumping sites on PEI. Observations indicate that enforcement of the regulations is increasing. These regulations—in concert with an opportunity to avoid the CAN$95 per ton landfill tipping fee[22]—provide strong motivation for PEI farmers to deliver used plastics to Island Plastics for recycling. A survey commissioned by Island Plastics shows that farmers are not seeing an economic benefit from recycling; therefore economics alone does not likely provide sufficient incentive to recycle rather than dispose on farm (O'Neill 2002).

Although Island Plastics has not been charging farmers a tipping fee for their plastics, neither have they been paying for the materials or covering shipping costs. Moreover—since Island Plastics sorts the plastics before re-processing and removes some of the dirtier materials for landfilling—the arrangement has put an economic burden on Island Plastics. The company takes on liability for landfill tipping fees when they receive plastics from farmers that are too "dirty" to recycle. In analyzing the economics of the recycling market, O'Neill (2002) recommends that Island Plastics no longer accept all quality of LDPE plastics directly from the farmer. Instead O'Neill recommends that Island Plastics should work in conjunction with the public sector to collect used farm plastics, and then take possession of only suitable plastic feedstock after the dirtier materials have been separated out for landfilling or incineration.

Thus—although Agri-Plas has built its reputation on its unique ability to process silage wrap, a product use that presumes some level of contamination—the fact that Island Plastics removes the dirtiest plastics from the recycling stream indicates that the RPL industry would benefit from better collection, sorting, cleaning at all stages in order to secure cleaner silage wrap for recycling. Along these lines, Island Plastics is considering adding a washing step to remove dirt prior to processing[23]. The literature from Agri-Plas and Island Plastics does not specify an acceptable level of contamination, although in personal communication, 20% was mentioned. We do not have data on how much of the plastic feedstock delivered for recycling is rejected due to contamination. It is not clear whether the Agri-Plas recycling equipment is unable to handle the higher level of contamination, if contaminated plastics are rejected because they would compromise quality of the end product, or if wear-and-tear on equipment from re-processing contaminated materials is simply not cost effective. O'Neill (2002) notes that the contamination thresholds may need to shift towards the cleaner materials as machinery shows wear.

This is 1160-1260 lb of plastic to wrap feed for his 150 cows, or 7.7-8.4 lb per cow) (personal communications with Martha Clarvoe, January 2003).

(2) A similar quantity per cow (7.5 lb of LDPE) per annum is estimated by a University of Vermont Extension bulletin Plastic Agricultural Film Recycling: A Cooperative Feasibility Study for Three New England States (April 1997) (cited by Arthur Amidon in personal communications with Martha Clarvoe).

(3) Amidon (1994) estimated that a 100-cow dairy in New England uses 1-2 large silage bags (8-12' x 100-250') per year. If each of these weighs 300 lb, then 6 lb LDPE silage wrap are generated per cow.

(4) An estimate of 150 lb per cow per year is derived from data from Island Plastic's financial officer Andy Adams, based on the assumption that one cow eats 10 round bales of hay in a year, each of which is wrapped with 15 lb LPDE plastic. If we can assume that the decimal point was misplaced in this estimate, and that each bale is wrapped in 1.5 lb plastic wrap, then the calculation that each cow generates 15 lb plastic wrap is in the same order of magnitude as the others. The difference between 7.5 and 15 lb could perhaps be accounted for by the longer winters in PEI and differences in farm practices in handling of animal feed.

[22] Note that the CAN$95 tipping fee in PEI is comparable to the US$60 tipping fee in New Jersey.

[23] As noted in Footnote 21, Trex™—the very large wood-plastic lumber recycling company based in Winchester, Virginia, and Fernley, Nevada—has also mentioned a plan to build a washing facility in 2003, which may indicate a potential outlet for "dirtier" agricultural plastics (personal communications with Ana Barros and Martha Clarvoe, Summer 2002).

HIGH DENSITY POLYETHYLENE (HDPE) (#2 RESINS)

On-farm uses of HDPE plastics. High density polyethylene is used to make rigid pesticide and nursery containers, and is also the feedstock for opaque, crinkly films.

Nursery containers. While some nursery containers are made from pure HDPE resins, many are made from previously recycled post-consumer plastics and industrial scrap, and thus are comprised of a mixture of resin types. These mixtures are less desirable as feedstock for a subsequent round of recycled end products—some of which have exacting feedstock specifications—than feedstock made from pure HDPE resins, such as recyclable milk or detergent bottles (Amidon 1994). Recycling life can be extended by using degraded resins for injection molded materials when no longer suitable for recycling into blow-molded pots. Such resin mixes have been subsequently re-used, for example, in producing Obex plastic lumber.

Quantities of pesticide containers generated and recycled. The Ag Container Recycling Council estimates that United States farmers use about 35 million plastic pesticide containers annually (ACRC 1999), of which about 20% were recycled in 1998. The trend toward increased recycling is evident (Table 1).

TABLE 1 PLASTIC PESTICIDE CONTAINERS, USED & RECYCLED NATIONWIDE (MILLIONS LB)

YEAR	GENERATED	COLLECTED	RATE
1989			
1990	24.7	0.35	1.4%
1991	21.9	0.84	3.9%
1992 est	20.0	1.28	6.4%
1993 est	19.0	2.50	13.2%

Source: Amidon 1994, Table II

YEAR	COLLECTED
1989	0.08
1990	0.30
1991	0.85
1992	1.28
1993	2.50
1994	3.65
1995	5.18
1996	5.94
1997	6.37
1998	6.78

Source: Ag Container Recycling Council 1999

Organizational infrastructure and economics of pesticide container recycling. The increase in recycled pesticide container plastics is due in large part to the work of the Ag Container Recycling Council (ACRC)—a group comprised of about 30 pesticide-manufacturing companies. ACRC contracts with a nationwide network of recycling companies to collect, granulate, and recycle agricultural pesticide containers. Because of funding and sponsorship from the pesticides industry—membership in ACRC is now required of all members of CropLife America[24]—this service is at no cost to agricultural pesticide applicators. Despite this, Denny (1999) judges that ten states—including New York State—had inadequate collection mechanisms in place in 1998[25].

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[24] CropLife America was formerly known as the National Agricultural Chemical Association.

[25] New York is one of only four states Denny judged to have an inadequate program both for collection of unusable pesticides and for collection of pesticide containers. It is the only one among the four that is a major agricultural state. Denny noted that New York collection was less than 17,000 lb per year—a quantity that could be generated by fewer than a dozen of the larger urban lawn care companies alone. In Denny's categorization scheme 10 states

ACRC was formed in 1992 as the Agricultural Container Research Council, an independent organization charged with collecting and granulating plastic pesticide containers and conducting research on viable end-uses for the recovered plastic. Initial research focused on potential public health and environmental risks from recycled pesticide containers. Once it determined that this risk was low, ACRC emphasis shifted to promoting collections, and the group was re-named the Ag Container Recycling Council. During the past 10 years ACRC has recycled 53 million lb of plastic—building capacity from one million lb in 1992 to more than 7 million lb per year by 1998. End-uses of the recycled HDPEs include new pesticide containers, marine pilings, field drainpipe, speed bumps, sub-flooring, plastic lumber and energy recovery (ACRC promotional literature).

In New York and throughout the eastern and southern United States, pesticide container recycling is handled by the Texas-based company USAg Recycling, Inc. As a service, USAg Recycling sometimes includes nursery containers in their pickups, but the recycling of pesticide containers is their chief mission. Typically USAg Recycling works with agriculture extension agents or others in similar roles who act as local collection coordinators to "champion" the cause, motivate participation and arrange for transport from farm to collection site[26]. Containers are either brought to a permanent collection center or to sites temporarily set up for recycling "events." Following collection, USAgRecycling takes their mobile granulation units to the sites; inspects the containers to guarantee they meet the collection criteria; and then grinds, bags and labels the granulates. Bags are trucked to recycling facilities approved by the ACRC (personal communication Tracy Moore, USAg Recycling, Inc., Aug 23, 2002).

Material preparation for recycling. Containers for recycling through ACRC programs must be clean, non-refillable HDPE plastics (#2) or other resins (#7) that originally contained an EPA registered pesticide or an associated adjuvant, oil or surfactant. They do not collect veterinary or consumer products, or home or garden pesticides. The containers must be empty; triple- or pressure-rinsed; dry; and with caps, metal handles, rubber liners, etc. removed. For current recycling criteria and collection information, contact ACRC or USAgRecycling (see http://www.acrecycle.org/materials.html).

Pennsylvania pesticide container recycling program model. Recent research in Pennsylvania has shown that permanent collection sites (*e.g.,* maintained by pesticide distributors) are more efficient and effective than sporadic recycling days (Gilbert 2001). In accord with these research findings, Pennsylvania has developed a statewide pesticide container recycling network with 140 permanent recycling sites in 52 of the state's 67 counties. About half are "public" locations where recyclable pesticide containers are collected from all types of licensed pesticide applicators, regardless of point-of-purchase. The others are "private" sites; *e.g.,* large agricultural or lawn care enterprises that collect containers only from their own pesticide applicators. Don Gilbert, coordinator of the Pennsylvania program, believes it is unique in its arrangements with private businesses for permanent collection sites. As detailed in Table 2, the Pennsylvania program owns equipment valued at more than $200,000 (Gilbert 2002; personal communication, Don Gilbert, Feb 20, 2003).

The Pennsylvania Pesticide Container Recycling Program is supported by landfill tipping fees and by pesticide product registration fees, fines, and business and applicator license fees. These moneys are

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are judged to have "competent" programs, the same number as have "inadequate" programs, while the bulk of states are judged to have "spotty" or "reasonably adequate" container collection programs.

[26] In his national report card on pesticide stewardship—in which New York State is portrayed in dim light—Denny (1999) sets forth criteria and conditions conducive to successful statewide pesticide container recycling programs (and likely applicable to any type of recycling program). Foremost is the need for a strong local advocate, with whom leadership can be consolidated. The advocate can be a statewide agency (the Department of Agriculture in North Carolina performs this role; in Texas it is the Natural Resources Conservation Commission), an organization (in Arkansas it is the Future Farmers of America), or an individual (an honor Denny gives to Dr. Larry Schultze of the Nebraska Cooperative Extension Service).

funneled through the Pennsylvania Department of Agriculture, which bears administrative costs (including granulation and removal), and the Department of Environmental Protection (DEP), which assumes program liability. The basis for this interagency cooperation is the Pennsylvania Recycling and Waste Reduction Act that requires Commonwealth agencies to promote development of recycling programs, the Administrative Code that requires interagency cooperation, and the funding available from Pennsylvania DEP to establish and implement recycling programs in conjunction with the Governor's Executive Council on Recycling Development and Waste Reduction. Equipment costs for this program are given in Table 2.

TABLE 2

PENNSYLVANIA PESTICIDE CONTAINER RECYCLING PROGRAM EQUIPMENT

Granulator truck	$ 90,000
Pickup trucks (2)	46,000
Box truck	28,500
Forklift	23,000
Storage units (145)	30,000
Rollback truck	10,000
TOTAL	**$ 227,500**

(source: Don Gilbert, coordinator, PA Pesticide Container Recycling Program

New Jersey pesticide container recycling program model. New Jersey's pesticide container collection program is organized differently, relying entirely on "recycling day events" and on recycling equipment brought to the sites by USAg Recycling, Inc. Local coordination of the state program has been under the auspices of NJDA Agribusiness Development representative Karen Kritz. As an incentive to participate in the program, Agribusiness Development arranged for participating licensed pesticide applicators to be given a unit of core credit toward New Jersey DEP recertification (NJDA 2002a, b). In addition to promoting and arranging for collection during the planning phases, Agribusiness Development arranges for state or county employees to assist during the "recycling days." Local staff handle quality control, issue the pesticide applicator credits, and assist USAg Recycling staff in processing the containers.

In 2002, five staff were deployed to each of three collection sites for a one-day annual collection, at an estimated $2,875 in in-kind staff time. In 2003, New Jersey is expanding its pesticide container collection program to two annual collection days and 5 collection sites, with three staff at each site. Each "recycling day event" will have a separate day for growers to bring their containers and another for USAg Recycling to process the materials (*i.e.*, grinding containers and then bagging the granulates). It is anticipated that processing will take place within a few days of delivery, so there will not be costs for storage, but additional local staff time will be needed to assist USAg Recycling with processing. It is anticipated that five people will assist at each site for six hours, at a cost of $3,750. In-kind labor costs for each recycling event are therefore estimated to be $6,750. With two collection events in the year, total in-kind labor costs are $13,500[27].

[27] In 2002 collection sites were open 7-8 hours, for a total of 23 hours among the three sites. With five state/county employees at each site, 115 staff hours were devoted to the collection process. Assuming employees are paid an average$25/hour, in-kind cost for state/county employee time was $2,875 (5 staff/site x (7 + 8 + 8 hours/staff) x

New York. New York has not had an ongoing, state- or regionally-organized pesticide container collection program comparable to either of these statewide models. Because USAg Recycling does not require agency or organizational involvement in pesticide container recycling events, it is possible that individual New York agribusinesses have been participating in pesticide container recycling by making independent arrangements with USAg Recycling.

Coordinating pesticide container recycling with pesticide "Clean Sweep" programs. In New York State and elsewhere some pesticide container recycling events have been coordinated with pesticide amnesty programs during which obsolete, banned and unwanted pesticides are collected, transported and disposed without fees, penalties or censure (a.k.a. "Clean Sweep"). However, New York has not had a statewide agricultural pesticide collection program. Local "Clean Sweep" programs took place in at least two New York counties during Fall 2002. USAg Recycling handled pesticide container processing and recycling in both of the following examples:

- The St. Lawrence County Farm Bureau partnered with the County Water Quality Coordinating Committee (WQC), funded by a $15,000 grant from the New York State Soil and Water Conservation Committee in a voluntary pesticide amnesty program that collected from active and inactive farms, golf courses, municipal facilities, schools, colleges, and universities (S&WC).
- The Department of Environmental Conservation's (NYS DEC) Bureau of Pesticide Management spearheaded a program that collected from four locations in Suffolk County, Long Island, funded by a negotiated compliance action against a pesticide registrant (Denny 2002).

NYC DEC is currently working to expand the "Clean Sweep" program (including both pesticide products and containers in the collections) across New York State. In so doing they are seeking to develop partnerships with county-based Cornell Cooperative Extension (CCE) associations to work on the educational aspects of the campaign (CCE News Feb 2003). A coalition that has included the New York Rural Water Association, the Northeast Rural Community Assistance Program and the New York Center for Agriculture, Medicine and Health has simultaneously been working with the New York State Assembly's Legislative Committee on Solid Waste to craft legislation authorizing state support for an ongoing, statewide "Clean Sweep" program (NYFPCP 2003).

In a number of states, "Clean Sweep" programs are funded by some combination of EPA grants, pesticide registration and licensing fees and state appropriations, sometimes also with modest user fees. Slingerland et al. (2002, p47) found that states funded by grants or tax-based funds collected twice the volume as states without a specific funding source. States relying on user and pesticide registration fees collected 25% more than states without a dedicated funding stream.

Incentives to participate in container recycling programs. Various incentives are being used to encourage participation by pesticide applicators and local solid waste authorities, including (a) pesticide applicator continuing education credits, as described in the New Jersey case; (b) coordination with pesticide collection amnesty programs, as described in the New York cases; and (c) state subsidy and legislative support, as described in the Pennsylvania case.

$25/hour = $2,875). In 2003 there will be a small increase in hours of operation on collection day, with $3,000 in-kind staff costs on that day (5 sites x 3 staff/site x 8 hours/staff x $25/hour=$3000), and an additional $3,750 in-kind staff costs on the day when materials are processed for recycling (5 sites x 5 staff/site x 6 hours/staff x $25/hour=$3,750). Total cost of labor for each collection event is therefore $6,750. With two collection days per year, labor costs double to $13,500 (calculations from personal communication, Karen Kritz, Feb 18, 2003).

POLYSTYRENE (PS) (#6 RESINS)

On-farm uses of polystyrene plastics. Nursery trays and flats, as well as some of the pots used for perennial plants, are made from this rigid plastic. The primary agricultural product returned for recycling are the "plug trays" that are discarded after transplanting nursery stock. Polystyrene (PS) is also widely used in the food distribution system—to make non-compressible, rigid foam drinking cups, meat trays and take-out containers, and disposable "silverware."

Recycling programs. The Canadian Polystyrene Recycling Association (CPRA) picks up and pays for full truckloads of palletized polystyrene nursery trays and flats. Full truckloads are approximately 24-26 pallets, each 800-1,000 lb. Payment to nurseries is at a rate commensurate with distance from the CPRA recycling plant in Mississauga, Ontario (near Toronto). Base price for 20,000 lb (10 ton) loads of polystyrene resin is $80/ton when picked up from New York State (excluding Long Island), New Jersey, Michigan, Ohio or Pennsylvania. Lesser amounts are paid from more distant locations, to compensate for the cost to CPRA for trucking (*e.g.*, $60/ton is paid for pickups on Long Island, New York), whereas a bonus of $20/ton is paid for loads greater than 20,000 lb (for details, see CPRA website http://www.cpra-canada.com).

Agricultural polystyrenes are processed with non-agricultural polystyrenes (such as fast food containers and industrial scrap) at the CPRA recycling plant, which has a capacity of 3,500 metric tons PS per year. Processing of used materials into pellets of PS resin takes about 40 minutes and involves sorting; granulating into flakes; washing, drying, melting the flakes; and then extruding (or forming) the resin into pellets. The pelletized PS is then sold to manufacturers of new products—such as construction materials, horticultural products like nursery trays, audio and video cassette and CD housings and cases, plastic hangers, office accessories like rulers and desktop containers, packaging "peanuts," and industrial reels and spools. Polystyrene can be recycled repeatedly since it maintains much of its integrity as it is melted and reformed. Costs for recycling are covered by sale of the recycled resin to manufacturers and by membership fees from industry members of CPRA. (CPRA website "Facts and Figures" from http://www.cpra-canada.com/facts.html).

The Canadian Polystyrene Recycling Association (CPRA) was founded in 1989 as an industry association of 24 companies, with members including resin producers, polystyrene product manufacturers, distributors and major end users of polystyrene products. Their primary purposes were public education about recyclability of polystyrene products, and development of a pilot manufacturing facility to demonstrate the commercial viability of recycling post-consumer polystyrene waste. With a $6.5 million capital investment, the polystyrene manufacturing facility in Mississauga began operation in 1991. Since 1995, CPRA been working with greenhouse growers and is now the largest horticultural polystyrene recycling facility in North America. Initially, greenhouse wastes came primarily from Southwestern Ontario and Northern Ohio, but CPRA is currently working with more than 150 greenhouse growers in two Canadian provinces and 27 states—including growers as far away as Southern Florida and Texas. CPRA representative John Roulston has expressed interest in working with New York State growers (personal communications, Feb 18, 2003).

Material preparation for recycling. CPRA accepts nested and stacked materials, from which excess soil and plant materials have been removed (washing is not necessary). Detailed instructions for preparing pallets of planter trays for shipping are given in *Polystyrene Recycling for the Greenhouse Grower* (CPRA undated).

SUMMARY AND CONCLUSIONS

Plastics have become ubiquitous in agriculture. They are used in the dairy industry as silage and haylage bags, bunker silo covers, bale wraps and twines; in the nursery industry, as hoophouse covers, trays and containers; in fruit and vegetable production, as row covers and mulch films; and in all agricultural sectors in pesticide containers. The primary objective of this report is to compile and evaluate information about recycling of agricultural plastic wastes (LDPE, HDPE and polystyrene resins) in order to facilitate development of an infrastructure in New York State for disposing of such plastics off-farm, thus avoiding the environmental health effects and other liabilities of burning, burying, or dumping on-farm. We have concluded from this research that:

- Substitution of plastics for the longer lasting materials previously used in agriculture (*e.g.*, silage bags in place of vertical silos, plastic hoop houses in place of glass greenhouses, etc.) is increasing because of production efficiency and economics.
- Additional research is needed to develop a good estimate of the quantities of plastics used in New York State agriculture, their rate of increase, and cost to farmers for their use and disposal.
- Evidence indicates that economic advantages of some agricultural plastics (*e.g.*, silage bags) accrue particularly to small farmers and those whose future in farming is uncertain, because the disposable products do not require a large capital investment.
- Health impacts from open burning of agricultural plastics (as well as household trash) are a significant concern.
- An estimated ≥ 50% of agricultural plastics are burned, and the remainder buried or dumped on-farm, based on survey data from New York and from Pennsylvania—a neighboring state that also does not have legislation prohibiting on-farm disposal.
- Agricultural plastics recycling in New York State has been constrained by the immaturity and volatility of recycling markets in general, compounded by the dispersed and relatively small quantities of agricultural plastics, as well as their oftentimes lower quality due to degradation by UV light and contamination with debris (*e.g.*, dirt, pebbles, vegetation, moisture, baling twine, etc.).
- New York does not legislate or regulate on-farm disposal of plastics, so there is no legal incentive for farmers to recycle.
- There has been little incentive, other than altruism, for New York State farmers to consider environmental health impacts in selecting recycling or landfilling over on-farm disposal.
- Developing an infrastructure for agricultural plastics collection and transport is a crucial preparatory step for an efficient recycling system. Before recycling markets can be developed, a sufficient stream of materials must be available.
- Experience has shown that successful recycling programs require a state or local agency or organization to "champion" the cause, *i.e.*, to motivate participation, make local arrangements for collection, and broker arrangements with re-processors.
- Most recycling analysts contacted in developing this report believe that a favorable policy climate is needed; *i.e.*, market economics do not provide sufficient incentive or stimulus for agricultural plastics recycling programs to succeed. Farmers are more likely to participate in recycling if they are constrained from using cheaper and easier on-farm disposal options, or are provided technical assistance and/or economic incentives to recycle.
- New Jersey and the Canadian Provinces have laws prohibiting burning and dumping, which provide incentive for farmers to take advantage of recycling programs. Experience and surveys have shown

that farmers in New Jersey and Prince Edward Island will travel further to recycle than farmers in Pennsylvania, which does not have such legal prohibitions.

- Despite the many constraints on agricultural plastics recycling, we identified recycling programs and initiatives underway in the Northeast United States and Canada for handling most types of plastic resins used in agriculture. These include:
  - a nationwide, industry-sponsored network for collecting **HDPE pesticide containers**;
  - an industry-sponsored program based in Ontario, Canada, that picks up, pays for, and re-processes **polystyrene nursery flats and trays** in both the United States and Canada;
  - an **LDPE greenhouse and nursery film** collection program in New Jersey that was opened to out-of-state producers in 2002;
  - an initiative in Connecticut to develop an industry cooperative for collection of **LDPE greenhouse films**, under auspices of the Connecticut Agricultural and Business Cluster;
  - a **plastic lumber re-processing technology** based in Prince Edward Island, Canada, capable of handling "dirty" LDPE plastics used in dairying; and
  - research and development of a **plastic fuel nugget** that can be burned for energy recovery.
- New York State has not taken good advantage of the industry-sponsored program for recycling HDPE pesticide containers, in which a nationwide network of recycling contractors is funded by pesticide manufacturers to granulate and transport collected HDPE pesticide containers to re-processors. Pesticide container recycling programs in Pennsylvania and New Jersey offer two contrasting models for statewide pesticide container recycling programs.
- There have been several local and regional pesticide container recycling programs in New York State that have operated in conjunction with "Clean Sweep" programs for collecting and removing obsolete pesticides. However, New York has not had an ongoing statewide program for collecting either pesticide products or containers, nor has there been an adequate funding mechanism for such programs. New York State's Department of Environmental Conservation is poised to expand the "Clean Sweep" program statewide. Given the industry subsidy and infrastructure for recycling pesticide containers, the operational models in numerous other states, and the personal, legal and environmental incentives to be rid of unusable hazardous wastes, such an effort seems ripe for success.
- Uses of LDPE plastic films have increased dramatically during the past decade, particularly in dairying. While some of the cleaner LDPE agricultural plastics can be moved through existing re-processing channels, "dirtier" films contaminated with agricultural debris present the greatest challenges for recycling.
- Handling the bulky, cumbersome and dirty LDPE plastic films has also been a considerable challenge, now made easier by development of baling and other equipment for these purposes.
- The best disposal options we identified for "dirty" LDPE plastics are a process designed to produce plastic lumber from silage bags and a system for co-mixing plastic fuel nuggets with coal for energy recovery. For both, however, contamination with debris, dirt, moisture, etc. introduce serious constraints—In the first case by premature wear-and-tear on equipment and in the second case, by increasing pollutant emissions.
- Research and development are needed for improved processes and equipment to reduce and remove accumulated debris (*e.g.*, by washing, agitation, or chemical action), and for recycling process that can better handle contaminated plastics, particularly the LDPE films that are increasingly more widely used in New York dairy farming.

- Product stewardship—involving plastics manufacturers in disposal and full life-cycle accounting—should be encouraged. For some products and resin types, such industry involvement and funding commitment is already in place. *(i)* The Canadian Polystyrene Recycling Association (CPRA) uses member fees from manufacturers of polystyrene products to partially fund recycling of nursery trays and flats (sale of the re-processed resin also funds the process). *(ii)* The Ag Container Recycling Council (ACRC)—comprised of pesticide manufacturers—funds a nationwide network of recyclers to collect and process plastic agricultural pesticide containers.
- The viability of regional or statewide recycling programs should be explored, given capital costs for plastic balers and other collection equipment, sporadic and seasonal plastic removal, dispersed feedstock for recycling, and the need for a critical mass of materials in order to be cost effective and engage the interest of handlers, brokers and re-processors.
- In order to develop business plans and budgets for recycling operations in New York State, research is needed to better understand the use and life cycle of plastics in New York State agriculture, *e.g.*, how products are used, quantities and trends, economics of use, and farmer incentives and constraints for recycling in various regions and sectors of New York State agriculture.

APPENDIX: ERAP SURVEY—"LET'S RECYCLE AGRICULTURAL PLASTICS!"

From our very limited sample of 33 survey responses, primarily from dairy farmers, we learned that more than half (n=17) would transport plastic to a baling station and that a few more (n=19) would participate in a recycling collection program if the equipment came on-site to process and remove the plastic. Six respondents indicated willingness to pay a tipping fee (of $10-$300 per year) to dispose of recyclables. The survey has thus far been administered only to several dozen willing respondents at summer 2002 Empire Farm Days—in a format targeting dairy farmers—and at the Northeast Master Gardeners Conference—in a format targeting nursery and greenhouse producers. The survey instrument is available for use in other venues (ERAP 2002a, b).

FIGURE 3. ERAP SURVEY—"LET'S RECYCLE AGRICULTURAL PLASTICS!"
ADMINISTERED AUGUST 2002, EMPIRE FARM DAYS

CORNELL Center for the Environment

Let's Recycle Agricultural Plastics

Empire Farm Days Aug 02

The purpose of this survey is to collect information on the use and disposal of agricultural plastics in New York State, in order to work towards developing better recycling options

1. Where do you farm?________________________________ **County**

2. What is your herd size? __________ **How many acres of hay do you harvest?** __________

3. How are agricultural plastics used in your farm?

Plastic use	How much per year?		Brand name & source	How is plastic disposed?: Burn on site	Leave on site (buried, stored, left in place)	Bring to a public landfill or transfer station	Return to the distributor	Recycle or Re-use	Hire a commercial hauler to take plastics off-site	How often?: once every several years	1-2 times a year	about every other month	about once a month	more frequently than once a month
☐ Bunker silo cover	# rolls:	sq':		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Bale wrap	# rolls:	linear':		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Silage bags (*e.g.* Ag-Bag)	# bags:	linear':		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Mulch film	# rolls:	sq':		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Pesticide containers	#:	size:		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Other:				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4. If your local solid waste transfer station had an agricultural plastic baler (to "package" plastics for recycling), would you bring your plastics to it?

☐ Yes, if my only cost was for transport. I would transport up to ________ miles

☐ Yes, and I would pay a tipping fee of up to $__________ per year (or $________ per ton) to have plastics disposed off-farm

☐ No. Please explain why not ________________________________

5. Do you contract with a pesticide application service that disposes of used pesticide containers from your premises? Yes No

My contract is with ________________________________

Your Comments (please continue on the back): ________________________________

Contact Information (optional): ________________________________ **May we contact you again?** Yes No

Name telephone number email address

If you have questions or would like more information about this survey, please contact the Environmental Risk Analysis Program, 213 Rice Hall, Ithaca, NY 14853, (607) 255-4765, envrisk@cornell.edu.

CONTACTS AND RESOURCES

Agriculture Container Recycling Council (ACRC)
1156 15th St NW, Suite 400, Washington DC 20005
(877) 952-2272 Toll free fax: (877) 951 2272 Local phone (202) 861-3144
info@acrecycle.org http://www.acrecycle.org

Ag Bag International Ltd.
Tim Murray, contact for Ag-Bag plastic film product recycling program
2320 SE Ag-Bag Lane , Warrenton, OR 97146 USA
(503) 861-1644 fax: (503) 861-2527 or toll-free phone and fax (800) 334-7432
http://www.ag-bag.com

American Plastics Council
http://www.plasticsresource.com/
Recycling information: http://www.plasticsresource.com/recycling/index.html

Amidon Recycling
Arthur Amidon
125 Burns Hill Road, Wilton New Hampshire, USA 03086-5113
(603) 654-6577 fax: (603) 654 6717 aamidon@tellink.net

Arrowchase, Inc. (Contract service provider to ACRC and CleanSweep NY)
Robert L. Denny II, President, Arrowchase, Inc.
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President, Chenango County Farm Bureau
1028 CR 19, Norwich, NY 13815
(607) 336-3546 Cell/voice Mail: (607) 226-1195 bradd@ve-z.com

National Pesticide Stewardship Alliance
(annual meetings have included sessions about pesticide container recycling)
1156 15th Street, NW, Suite 400, Washington, DC 20005
(877) 920-NPSA fax: (877) 922-NPSA http://www.npsalliance.org/

New Jersey Agricultural Plastics Recycling Program
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New York State Association for Reduction, Reuse and Recycling (NYSAR3)
http://www.nysar3.org
Michele LaDue Benjamin, Region 7 - Central New York representative to the NYSAR3 Board
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Pennsylvania Plastic Pesticide Container Recycling Program
Don Gilbert, Coordinator
Pennsylvania Department of Agriculture, Harrisburg, PA
dgilbert@state.pa.us

Penn State University, Department of Agricultural and Biological Engineering
James W. Garthe, Instructor of Agricultural Engineering
(Contact re: agricultural plastics recycling and disposal, including research on fuel nuggets derived from "dirty plastics")
(814) 865-7154 jwg10@psu.edu
Solid Waste Fact sheets: http://www.age.psu.edu/extension/factsheets/c/

Plastic Lumber
Plastic Lumber Trade Association
P.O. Box 80311, Akron, Ohio 44308-9998
Voice/fax: 330-762-1963 http://www.plasticlumber.org/

Agri-Plas Systems (technology for manufacture of lumber from agricultural plastics)
Austin Boyd, CEO, Agri-Plas Systems 2000 Inc.
52 Matwood Drive, Stratford, Prince Edward Island, CANADA C1B1K6
(902) 569-1368 austin@pei.aibn.com http://www.agriplas.ca

Island Plastics Inc. (manufacturing plant using Agri-Plas technology)
Andy Adams, Financial Administrator, Island Plastics Inc.
240 Mason Road, Stratford, Prince Edward Island, CANADA C1B2V5
(902)-894-7527 fax: (902)-894-4746 andyadams@plasticlumber.ca
http://www.plasticlumber.ca

TREX Company (manufacture lumber from 50-50 mix of recycled wood-plastic)
Winchester, Virginia
Dan Fling, Northeast representative: 315-781-3200.
Mark Vatuna, Director of Materials: 1-877-319-9795
Paul McIntosh: 217-245-4329
Recycling information: 1-877-319-9795 http://www.trex.com

Polystyrene Recycling
see Canadian Polystyrene Recycling Association

Re-Sourcing Associates Inc
Seattle, Washington Plastic Film Recycling: http://www.rsarecycle.com/plastic.shtml

Tiger Baler LLC (agricultural plastics baler)
Dennis Sutton
411 65th Street Ct.. N.W., Bradenton, Florida 34209
(941) 761-8293 fax: (941) 792-5603 dennis44@tampabay.rr.com
http://www.tigerbaler.com/index2.html

USAg Recycling, Inc. (ACRC contractors for pesticide container recycling in New York State)
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Sam Gibson, President and CEO samg@usagrecycling.com
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Agri-Plas c	Agri-Plas Systems 2000 Inc. undated and untitled. (General information about Agri-Plas Systems) 1page.
Agri-Plas d	Agri-Plas Systems 2000 Inc. undated. *Agri-Plas Lumber Questions and Answers*. 2 pages.
Agri-Plas e	Agri-Plas Systems 2000 Inc. undated and untitled. (Hazards of burning agricultural plastics) 2 pages.
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