The Pollution Prevention and Biodiversity Enhancing Benefits of Curbside Recycling

by
Jeffrey Morris*

Many recycle because they believe that recycling protects our environment and is a more sustainable way to manage discards than landfilling waste materials or incinerating them in a waste-to-energy (WTE) facility. Recent studies provide strong empirical evidence for these beliefs.

The Problem

Revenues from selling recycled materials and savings from avoiding garbage collection and disposal costs often are not sufficient to cover the costs of recycling. At the same time, recycling has ecological and sustainability benefits that are not reflected in either recycling market revenues or avoided garbage costs.

Recycling is, thus, a prime example of the failure of competitive markets to correctly cost and price goods and services that provide ecological and sustainability benefits. From the societal point of view the result of this competitive market failure is that we under-invest in recycling and over-spend on garbage.

This article lays out results from a Washington State case study on some of the ecological benefits of residential curbside recycling – namely the reduction in various types of pollution. These reductions are indicative of the pollution prevention (P2) benefits yielded by recycling. This *UnEconomist* article also outlines results from a comprehensive Australian study on the benefits and costs of curbside ("kerbside" in the Australian spelling), including the biodiversity enhancing benefits of recycling.

These two studies show that when ecological impacts are included, curbside recycling's overall societal benefits do indeed outweigh its costs. The challenge then becomes finding policy measures that will offset the competitive market's failure to allocate enough scarce resources to recycling. A review of policies that have proven to be particularly effective at overcoming these market failures will be provided in the next issue of *The Monthly UnEconomist*.

Washington State Case Study Overview

Figure 1, Recycling per Curbside Available Household in Four Washington State Regions, shows monthly pounds recovered on average from each household eligible for curbside collection in communities from four regions of Washington state – urban areas west of the Cascade Mountains, urban areas east of the Cascades, rural areas west of the Cascades, and rural areas east of the Cascades.[1] Figure 2, Net Cost for Curbside Recycling in Four Washington State Regions, shows the net monthly cost per household for curbside, where net cost equals curbside recycling costs minus recycling market revenues, and minus avoided garbage transfer and disposal costs.[2]

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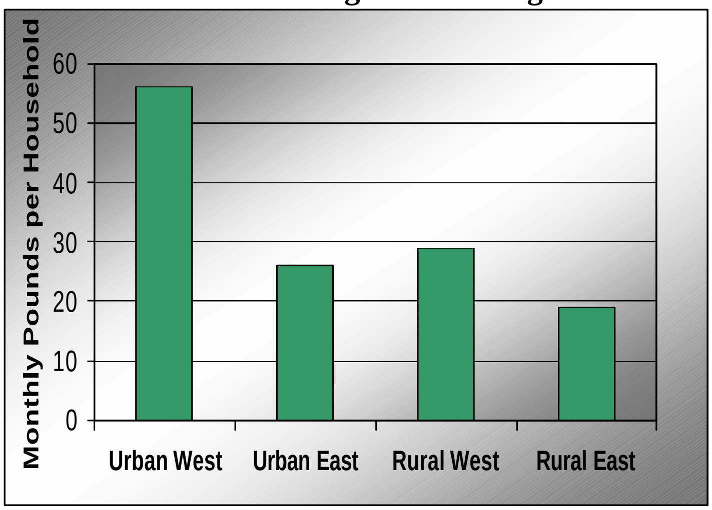
[1] Further details on the statistical data and methods used to gather information and generate the results reported herein are provided in *The Monthly UnEconomist* for May 2001. Life cycle data on energy use and pollutant releases are from Research Triangle Institute's Decision Support Tool (DST) for Municipal Solid Waste Management developed by RTI and others under contract to US EPA.

[2] Curbside recycling also avoids some portion of garbage collection costs, especially when recycling diverts a significant portion of waste. However, we were not able to gather reliable data on garbage collection costs for most of the communities covered by this study.

The two charts are indicative of a general conclusion – namely, that the costs of curbside recycling tend to be lower when the amount collected per eligible household is higher, other factors remaining equal. The main reason for this result is that economies of scale kick in strongly when more material is picked up during each stop of the curbside recycling truck.[3]

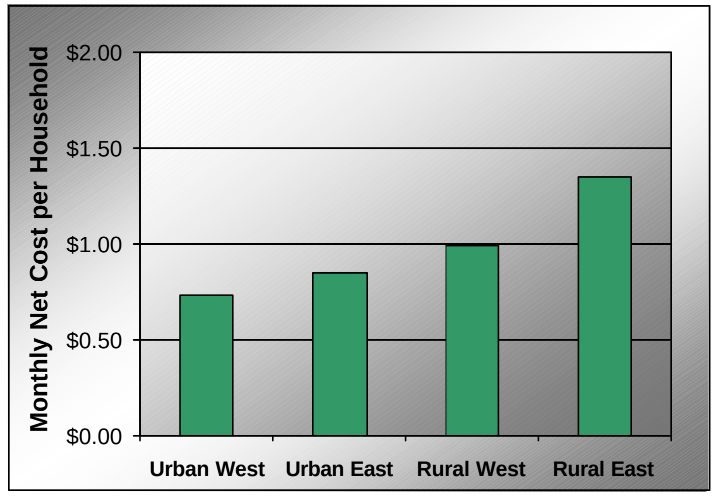
Figure 1
Recycling per Curbside Available Household in Four Washington State Regions



Two of the factors that are not equal in different regions of Washington State are housing density and types of materials collected. Collection routes in rural areas involve longer distances between stops, increasing the costs that must be charged to each household on the route. In addition, mixed paper is not typically collected curbside for recycling in the urban east and glass is not collected in the rural east. As a result of the exclusion of mixed paper and glass, respectively, from curbside recycling collections in the urban east and rural east, these two regions recycle fewer pounds per household than households in the urban west and rural west, respectively.

[3] Depending on the additional cost of adding a new material to curbside collection compared with its market value and avoided disposal costs, adding a new material may violate the generalization that collecting more weight reduces costs per household.

Figure 2
Net Cost for Curbside Recycling in Four Washington State Regions



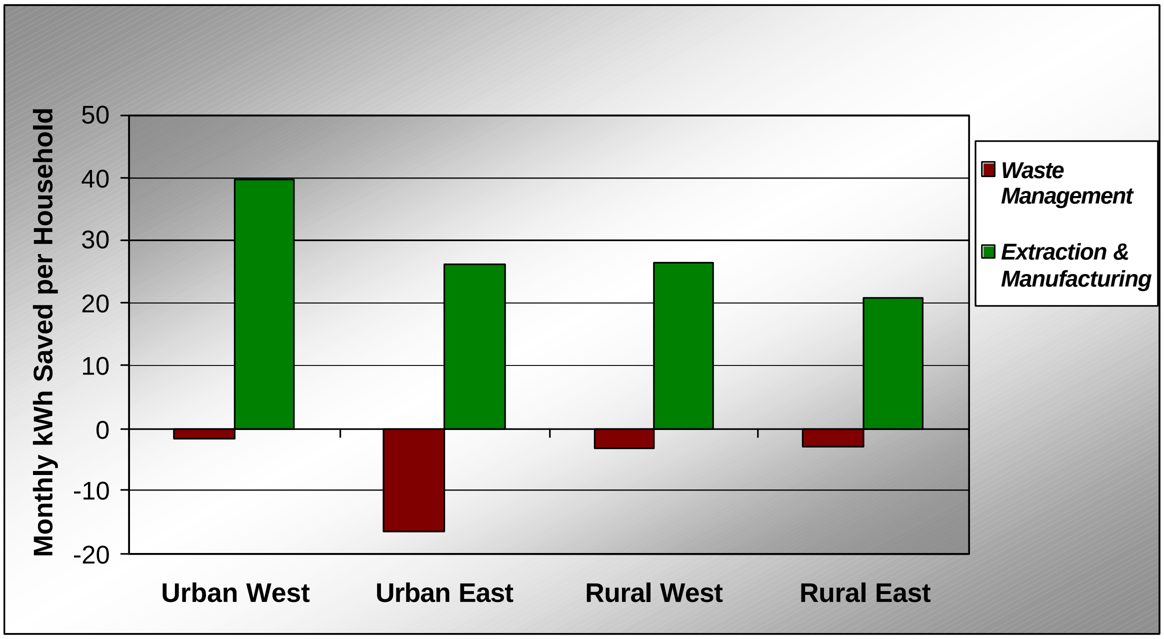
Energy Conservation from Curbside Recycling In Washington State

Energy use is often a reliable indicator of pollution intensity. Figure 3, Energy Use Reductions from Curbside Recycling in Four Washington State Regions, shows the energy conserved in each region when materials are recycled curbside rather than being collected in the garbage.

The right hand, green bars show the net energy saved by using recycled materials to manufacture products, instead of extracting and refining virgin raw materials to manufacture products. The left hand, dark red bars show the net energy expended from adding curbside recycling to the garbage collection and disposal system in each region. The overall energy savings from curbside recycling equals the energy saved by reducing the use of virgin raw materials, less the increased energy required to add a curbside recycling system to an already existing garbage collection and disposal system.[4]

[4] The life cycle of a product includes three stages -- resource extraction and manufacturing (often called the "upstream" stage), product use, and management of the discards when the product's useful life ends. Whether a product is made from recycled materials or virgin raw materials, the ecological impacts of the use stage will typically be identical. Thus, we focus on energy use and pollutant releases only for the extraction/manufacturing and waste management stages.

Figure 3
Energy Use Reductions from Curbside Recycling in Four Washington State Regions



In three of the four regions, communities included in our study send all of their collected garbage to landfills. The exception is the urban east where 90% of collected garbage is sent to a WTE facility. As a result, the waste management system bar in Figure 3 for the urban east region shows a much larger negative (i.e., increased usage) energy impact from curbside recycling because the recycled paper and plastic materials cannot be burned to generate energy when they are recycled.

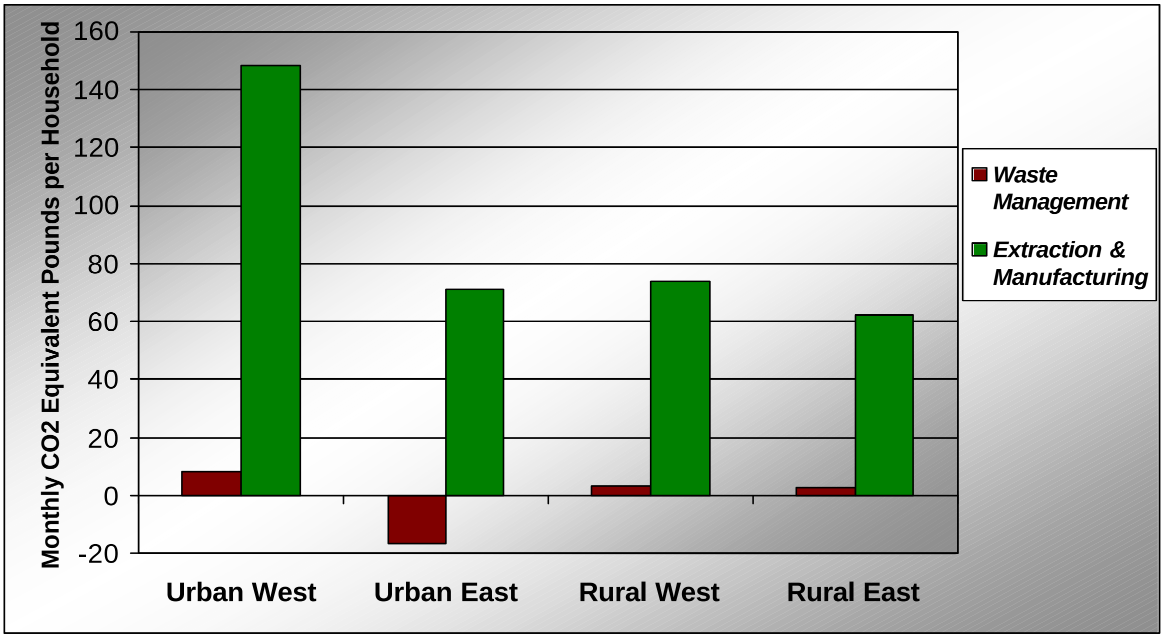
However, it is important to note that curbside recycling still conserves 59% more upstream energy than it loses in the waste management system by running recycling trucks and not burning paper and plastics to recover their energy content.[5] On balance, then, curbside recycling saves substantial energy in all four regions of Washington State regardless of whether disposal is via landfill or WTE incineration.

Pollution Prevention from Curbside Recycling in Washington State

The fact that curbside recycling saves energy in all four regions of the state, regardless of whether disposal is via landfill or WTE, foreshadows the discussion in this section on the pollution prevention benefits of curbside. In fact, energy use is often a good surrogate for environmental impacts because energy production and use is associated with releases of so many pollutants to the air, water, and land. This generalization holds true for curbside recycling versus garbage collection and disposal for four different indicators of potential damage from pollution -- global warming, acidification, eutrophication, and human toxicity.

[5] For a detailed comparison of energy conserved by recycling versus energy generated through WTE incineration see *The Monthly UnEconomist*, Vol. 2, Nos. 2-4 (February, March, and April 1999). This study is also reported in Morris, Jeffrey, "Recycling versus incineration: An energy conservation analysis," *The Journal of Hazardous Materials*, Vol. 47 (1996), pp. 277-293. There is also a brief, summary version in Morris, Jeffrey and Diana Canzoneri, "Comparative lifecycle energy analysis: theory and practice," *Resource Recycling*, Vol. XI, No. 11 (November 1992).

Figure 4
Reductions in Global Warming Potential from Curbside Recycling in Washington State



Global Warming

Figure 4, Reductions in Global Warming Potential from Curbside Recycling in Washington State, shows the impacts of curbside on greenhouse gas generation per household eligible for curbside recycling. Specifically, Figure 4 summarizes the global warming potential from releases of two pollutants – carbon dioxide and methane.[6] Other atmospheric releases also contribute to global warming potential – nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. However, U.S. EPA does not include these pollutants in their life cycle database on solid waste discards.

As indicated by Figure 4, curbside recycling substantially reduces the global warming potential of waste management compared with garbage collection and disposal, whether disposal is by landfill or WTE. In fact, in the three regions that depend on landfill disposal the impact on global warming from recycling collection trucks, materials processing, and transport of processed materials to markets is less than the impact of methane generated when paper is landfilled.[7]

On the other hand, disposal in a WTE facility in the urban east region would yield a net reduction in generation of CO_2, due to WTE generating less CO_2 per kilowatt than the northwest electric power grid. However, CO_2 reductions from WTE are overwhelmed by reductions in upstream CO_2 generation that accrue when virgin materials extraction, processing and manufacturing is replaced by using curbside recycled materials to manufacture new products. Also, recycling paper provides carbon sequestration in the trees not harvested for virgin-content paper products.[8] Even more than with energy use, the reduction in virgin materials extraction and manufacturing caused by recycling has a much more substantial effect on reducing global warming potential than does recovery of energy from paper and plastics in a WTE facility.

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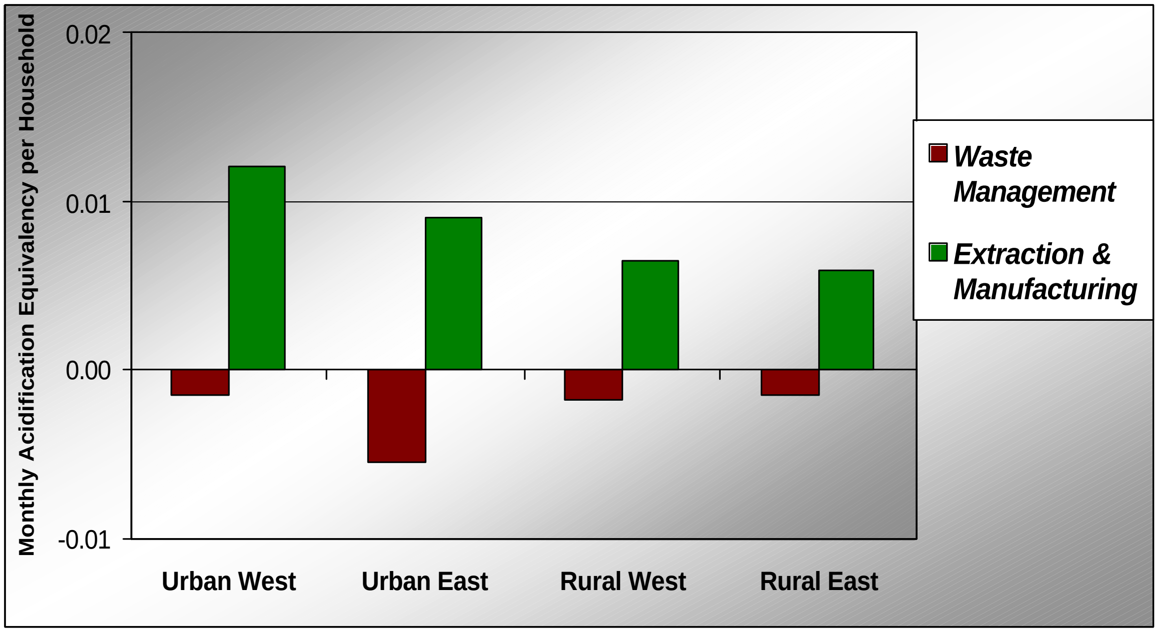
[6] Methane has a global warming potential 24 times larger than carbon dioxide, so increases or reductions in methane releases are multiplied by 24 and added to carbon dioxide releases to calculate the index shown in Figure 4.

[7] The calculations used to produce Figure 4 assume that all landfills have landfill gas collection systems that capture and flare methane generated by decomposing fibers.

[8] Carbon sequestration calculations used for Figure 4 are from U.S. EPA's WARM model available at www.epa.gov/globalwarming/actions/waste/warm.htm.

Figure 5
Reductions in Acidification Potential from Curbside Recycling in Washington State



Acidification

Figure 5, Reductions in Acidification Potential from Curbside Recycling in Washington State, shows the impact of curbside recycling on the acidification potential from releases of atmospheric pollutants. The acidification index for Figure 5 uses hydrogen as the reference substance, just as the global warming index for Figure 4 uses carbon dioxide as the referent.

Acidification affects trees, soil, buildings, animals, and humans. Fossil fuel use and biomass combustion are principal sources of two of the compounds that cause acidification – sulfur and nitrogen compounds.

Specific atmospheric pollutants that cause acidification are sulfur oxides, nitrogen oxides, ammonia, hydrogen fluoride, and hydrogen chloride. EPA's data include life cycle releases for all of these except hydrogen fluoride. The bars shown in Figure 5, thus, provide a comprehensive measure of the benefits of curbside recycling in reducing acid rain and other damaging effects caused by releasing acidifying pollutants.

As indicated by the bar graphs in Figure 5, curbside recycling reduces the acidification potential from waste management activities in urban and rural areas across Washington State regardless of whether disposal is by landfill or WTE. As was the case with energy savings and reductions in global warming potential, recycling's advantage in reducing acidification potential is less when WTE is used for disposal rather than landfilling. Nonetheless, to decrease the acidification potential of waste management activities, using recycled materials in place of virgin raw materials to manufacture products is more effective than generating electricity by incinerating otherwise recyclable materials.[9]

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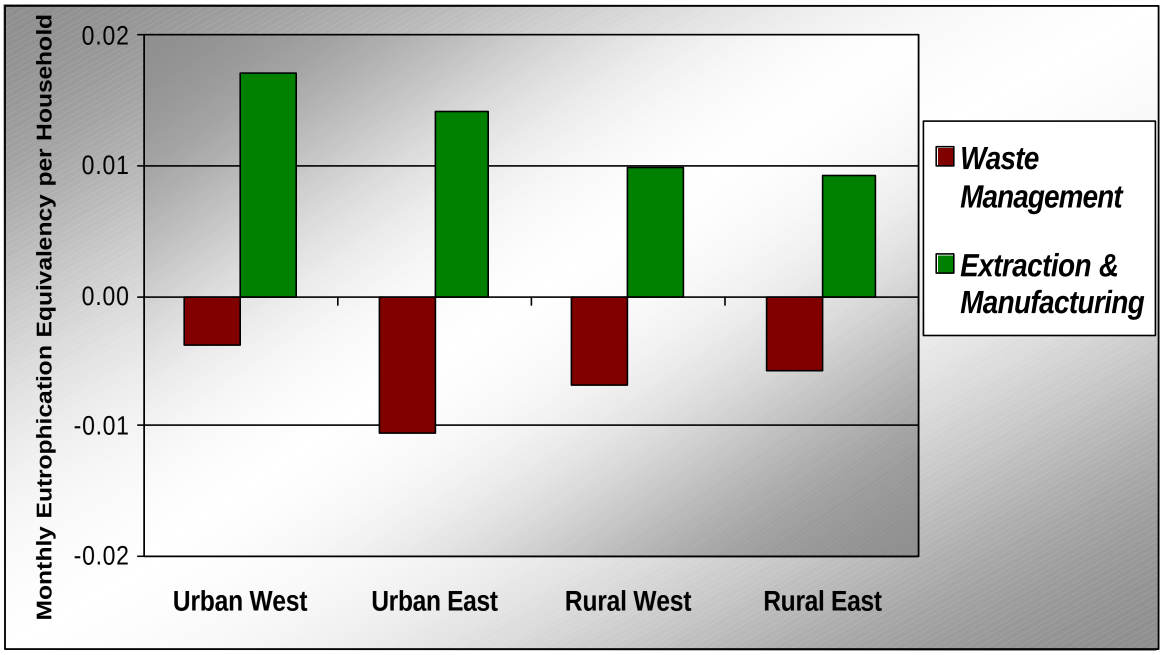
[9] The acidification potential index we used to generate Figure 5 is based on weights for acidifying pollutants that are reported in the manual for BEES (Building for Environmental and Economic Sustainability) software. The Center of Environmental Science (CML) at Leiden University developed the weights in CML, *Environmental Life Cycle Assessment of Products: Background*, Leiden, The Netherlands, October 1992.

NIST (National Institute of Standards and Technology) Building and Fire Research Laboratory developed the BEES model with support from U.S. EPA's Environmentally Preferable Purchasing Program and the White House sponsored Partnership for Advancing Technology in Housing (PATH). The model provides a quantitative method for balancing the environmental and economic performance of building products. Software and manual are available at http://www.bfrl.nist.gov/oae/software/bees.html.

Figure 6
Reductions in Eutrophication Potential from Curbside Recycling in Washington State



Eutrophication

Figure 6, Reductions in Eutrophication Potential from Curbside Recycling in Washington State, shows the impact of curbside recycling on the eutrophication potential from releases of atmospheric and waterborne pollutants. The eutrophication index shown in Figure 6 uses phosphate as the reference substance, just as the global warming index shown in Figure 4 uses carbon dioxide as the reference substance.

"Eutrophication is the addition of mineral nutrients to the soil or water. In both media, the addition of large quantities of mineral nutrients, such as nitrogen and phosphorous, results in generally undesirable shifts in the number of species in ecosystems and a reduction in ecological diversity. In water, it tends to increase algae growth, which can lead to lack of oxygen and therefore death of species like fish."[10]

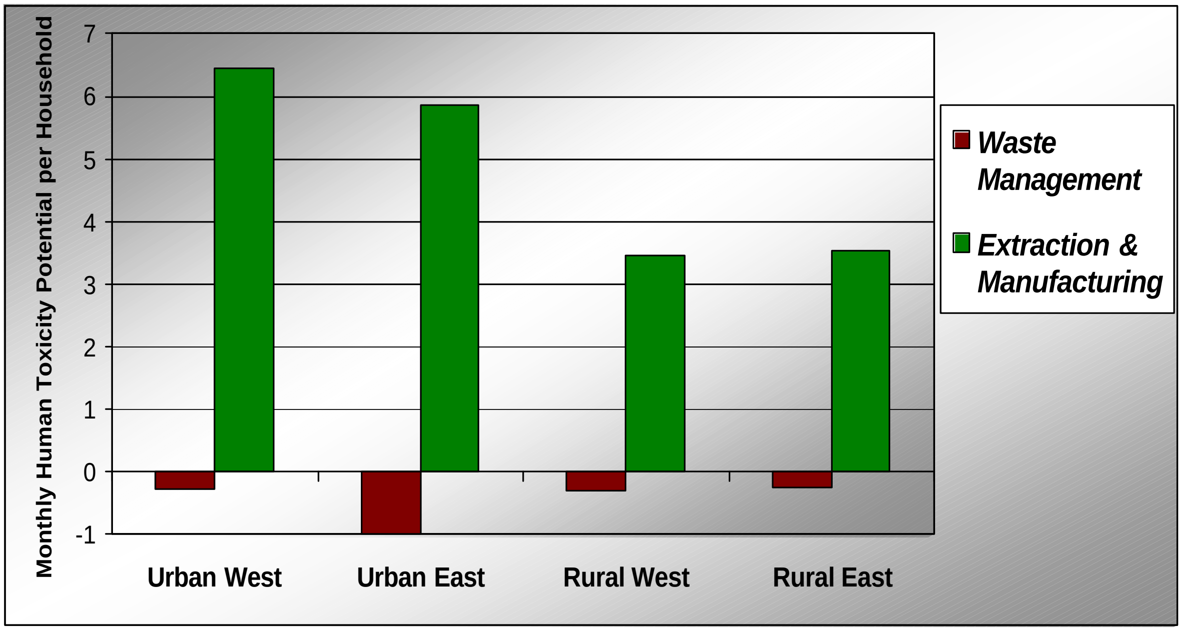
Specific atmospheric or waterborne pollutants that contribute to eutrophication include phosphates, nitrogen oxides, ammonia, nitrogenous matter, nitrates, phosphorous, and chemical oxygen demand (COD). EPA's data include life cycle releases for all of these pollutants other than nitrates and phosphorous. The bars shown in Figure 6, thus, provide a reasonably comprehensive measure of the benefits of curbside recycling in reducing impacts caused by releases of eutrophying pollutants.[11]

As indicated by the bar graphs in Figure 6, curbside recycling reduces the eutrophication potential from waste management activities in urban and rural areas across Washington State regardless of whether disposal is by landfill or WTE. Recycling's advantage is less when WTE is used for disposal rather than landfilling. However, to reduce the eutrophication potential from waste management activities, using recycled materials in place of virgin raw materials to manufacture products significantly outweighs generating electricity by incinerating otherwise recyclable materials.

[10] BEES Manual, *op. cit.*, page 13.

[11] The eutrophication potential index we used to generate Figure 6 is based on weights reported in the BEES software manual. The weights were developed by the Center of Environmental Science at Leiden University and are documented in CML, *op. cit.*, 1992.

Figure 7
Reductions in Human Toxicity Potential from Curbside Recycling in Washington State



Human Toxicity

Figure 7, Reductions in Human Toxicity Potential from Curbside Recycling in Washington State, shows the impact of curbside recycling on the potential for human toxicity from releases of atmospheric and waterborne pollutants. The human toxicity index shown in Figure 7 uses benzene for carcinogens and toluene for non-carcinogens as referents.

Human toxicity potential (HTP) indices shown in Figure 7 are calculated indices that reflect the potential harm of a unit of a chemical released into the environment via the atmosphere or surface water. The index weights for each chemical compound are based on both the inherent toxicity of a compound and its potential dose.[12]

EPA's life cycle release data for solid waste materials includes information for releases of twelve chemical substances that have a known potential for toxic impacts on humans, with data on two of the twelve measuring both atmospheric and waterborne releases. However, HTP index weights are available for 330 compounds (258 of which are listed in EPA's Toxics release Inventory). Thus, the results shown on Figure 7 are not comprehensive for all substances released during the life cycle of products. For example, atmospheric releases of mercury and atmospheric or waterborne releases of dioxins currently are not covered by EPA's database.

At any rate, as indicated by the bar graphs in Figure 7, for the substances tracked by EPA's DST database, curbside recycling reduces human toxicity potential from waste management activities in urban and rural areas across Washington State regardless of whether disposal is by landfill or WTE. Recycling's advantage is slightly less when disposal is by WTE rather than landfilling. However, to substantially reduce the potential for

[12] Weights used to calculate the HTP indices in Figure 7 were originally reported in Hertwich, Edgar G., *et al*, "Human toxicity potentials for life cycle assessment and toxics release inventory risk screening," *Environmental Toxicology and Chemistry*, Vol. 20, No. 4 (2001), pages 928-939. Hertwich is associated with the LCA Laboratory in the Department of Product Design Engineering at the Norwegian University of Science and Technology, Trondheim, Norway. Index weights have since been updated. The updates are available online at http://design.ntnu.no/ansatte/hertwich.

human toxicity impacts from waste management activities, using recycled materials in place of virgin raw materials to manufacture products overwhelmingly outweighs generating electricity by incinerating otherwise recyclable materials.

Other Measures of P2 Benefits from Recycling

In preparing this report we could also have evaluated curbside recycling according to other measures or indicators of the ecological and sustainability impacts of waste management choices. For example, the BEES software evaluates building products on the basis of global warming potential, acidification potential, eutrophication potential, natural resource depletion, indoor air quality impacts, and solid waste impacts. In addition, BEES software version 2.0 pilot tests four additional impacts – smog, ecological toxicity, human toxicity, and ozone depletion.

Unfortunately, EPA's database for the life cycle of solid waste materials is inadequate at this time to make calculations of the potential for natural resource depletion, smog formation, ecological toxicity and ozone depletion from solid waste management choices. Indoor air quality impacts are more relevant for the use stage of a product's life cycle rather than the resource extraction/manufacturing and waste management stages covered by the analysis in this report. Finally, solid waste impacts are shown in Figure 1, Recycling per Curbside Available Household in Four Washington State Regions, in terms of the weight of materials diverted from disposal through collection in a curbside recycling program.

Australian Curbside Recycling Study

A study of curbside recycling in Australia evaluated ecological and sustainability impacts for curbside recycling versus landfill disposal. The study is of interest because it developed estimates for the monetary value of curbside recycling's external benefits (including avoided external costs of virgin materials use) that result from reductions in pollution, natural resource use, land use, and biodiversity impacts.

As explained in the study, "The inclusion of environmental benefits (expressed in dollar terms) together with current recycling and collection system costs provides an overall average benefit of $42 per household per year. This comprises an average net financial cost of $26 per household per year and an average environmental benefit of $68 per household per year…

"The Life Cycle Assessment (LCA) component of the study included modeling of more than 50 substances – resource inputs and pollutant outputs for each aspect of the collection and recycling system. Consideration was given to both the kerbside system and the product system (when materials are recycled the impacts of production are avoided -- including life cycle stages of virgin materials acquisition, refining and some aspects of manufacture).

"…Once the LCA data was modeled for each system under study, it was aggregated into environmental impact categories and then valued by applying environmental economic benefit assessment techniques based on published Australian government references.

"The analysis indicates that the average national environmental benefit of current kerbside collection and recycling systems in metropolitan and regional centers is conservatively estimated to be $68 per household per year (between $41 and $119 depending on the system and location).

"…The average additional benefit of the recycling system is $71 per household per year. The majority of this comes from the air and water emissions associated with avoided product credits during manufacture from virgin materials.

"Of less significance are the (negative) impacts associated with the collection system (around $3 per household per year). The findings defy a commonly held perception that the environmental cost of collection may be greater than the environmental benefit of recycling."[13]

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[13] Nolan-ITU, SKM Economics, and ENVIROS/RIS, *Independent Assessment of Kerbside Recycling in Australia*, Australian National Packaging Covenant Council, January 2001. The quotes are extracted from the Executive Summary, pp. III-VII. To download the report, go to Home Page from http://www.packcoun.com.au.

As indicated by the quote above, the study concluded that curbside recycling's environmental benefits (based on the estimated monetary value of external benefits) substantially exceeds its net costs (collection + processing + shipping – market revenues – avoided garbage collection and disposal costs). The study figured that curbside's net cost is just 38% of the dollar value of its overall net ecological benefits.[14]

- 75% of this overall ecological benefit is from reductions in air and water pollutant emissions associated with the use of virgin raw materials to manufacture products.
- 21% of the benefit is from land use, biodiversity, and future resource access benefits resulting from reduced mining and harvesting of mineral and forestry resources.[15]
- 4% of the benefit is from global warming credits.
- 2% of the benefit is from reduced land use for landfills.
- Ecological costs of increased truck traffic offset just 2% of these overall benefits. (Note that a 2% offset for the ecological costs of increased truck traffic to collect, process, and transport recycled materials is very small compared with 98% for "upstream" benefits of recycling due to reduced virgin materials and energy extraction, refining, and use in manufacturing products.[16] This relationship between upstream environmental benefits and waste management system environmental costs was first illuminated to a wide audience by Tellus Institute's study for The U.S. Council of State Governments on the environmental impacts of packaging materials.[17])

[14] The Australian kerbside study followed the same methodology as our Washington State curbside study did. That is, all results are calculated for the incremental effect of recycling by comparing a garbage collection/disposal plus curbside recycling system against a garbage collection/disposal only system.

[15] "The adoption of a zero value for forest resources reduces the net environmental benefit by 6% from $68 to $64 per household per year. Forest valuation is the least certain value used." Nolan-ITU, *et al*, *op. cit*., p. VIII.

[16] As indicated in footnote 4, "Upstream" typically refers to that part of a product's life cycle that is upstream from its use and waste management stages – i.e., "upstream" refers to the raw materials and energy extraction, refining, and manufacturing stage, termed the "Extraction & Manufacturing" stage in the charts shown in this article.

Concluding Observations

Both curbside recycling studies reviewed in this article concluded that the global ecological benefits of recycling far outweigh its local economic costs. The Australian study included more pollutants in its life cycle assessment than did the Washington State study (22 atmospheric and 23 waterborne pollutants in the Australian study versus 10 and 17, respectively, in the Washington State study). The Australian study also estimated monetary values for the biodiversity enhancing and resource conservation benefits of recycled-content over virgin-content product manufacturing. This additional scope in the Australian study resulted in a solid conclusion that the monetary value of external benefits from curbside recycling substantially exceeded recycling's net costs.

While more limited in scope due to having life cycle inventory data on fewer pollutants, the Washington State study also showed conclusive evidence for the environmental benefits of curbside recycling in terms of both substantial reductions in energy use and sharply decreased impacts from pollutant releases on global warming, atmospheric acidification, euthrophication, and human toxicity. The Washington State study also provided evidence for the superiority of curbside recycling over both landfill and WTE incineration, whereas the Australian study only covered the landfill disposal option.

[17] Tellus Institute, *CSG/Tellus Packaging Study: Assessing the impacts of production and disposal of packaging and public policy measures to alter its mix*, The Council of State Governments, U.S. EPA, and New Jersey Department of Environmental Protection and Energy, May 1992.

About The Monthly UnEconomist

This monthly online newsletter available at www.ZeroWaste.com (or www.SoundResource.com) intends to provide insight and analysis on the everyday economics of recycling and the unpriced or underpriced environmental benefits of reducing waste disposal and replacing virgin-content products with products manufactured from recycled materials. In addition to *The Monthly UnEconomist*, Sound Resource Management's website ZeroWaste.com also offers recycling markets price history graphs, reports on a variety of topics including the economic and environmental benefits of recycling, and GarboMetrics - elegant, yet not mysterious tools and spreadsheet models for solid waste and recycling.

These materials are all available for no charge at www.ZeroWaste.com. User feedback is encouraged via info@ZeroWaste.com, and substantive comments will be published in our newsletter whenever they add to our understanding of recycling.

As an example of newsletter content, some issues of the *UnEconomist* analyze northwestern and northeastern U.S recycling market prices for nine recycled materials (mixed paper, ONP, OCC, glass containers, tin cans, UBC, PET bottles, HDPE natural bottles, and HDPE colored bottles). These prices are tracked by online graphs updated quarterly.

In addition, some issues of the *UnEconomist* are devoted to GarboMetrics, economic models for managing and analyzing solid waste and recycling. These newsletter issues explain the structure and use of GarboMetric models provided at ZeroWaste.com for such purposes as designing garbage customer rate structures and correctly comparing garbage rates in different communities. GarboMetric models and corresponding issues of *The Monthly UnEconomist* can be downloaded at no charge from www.ZeroWaste.com