

The Association of Plastic Recyclers White Paper:
**Virgin vs. Recycled Plastic Life Cycle Assessment Energy Profile
and Life Cycle Assessment Environmental Burdens**

May 12, 2020

Executive Summary:

In life cycle assessments energies are categorized into two groups: expended energy and inherent energy. Expended energies are the energies of transportation and energies used to operate processes. Expended energies are energies used and lost. Inherent energies are the fuel value of the material and are not lost except to combustion or disposal.

There are several conventions in life cycle assessments with regard to inherent energies and recycling. The Cut-Off method assigns all of the inherent energy to the first, or virgin, use. The Open Loop method shares all of the virgin inherent and expended energies and recycling expended energies over two or more uses of molecules. The Cut-Off method has fewer assumptions and allocations and is readily understood. Comparing the inherent and expended energies of virgin plastics with just the expended energies of recycled plastic is valid, but easily misunderstood and creates a bias for the recycled plastic.

Comparing just the expended energies of recycled PET, high density polyethylene (HDPE) and polypropylene (PP) shows the virgin plastic expended energies are 1.7, 3.0 and 3.0 times the expended energies of postconsumer recycled plastic. Recycled plastic is more conserving of expended energy than is virgin plastic. As practiced today, plastics recycling is a lower energy process than the process to synthesize the plastic resins from basic chemicals.

Background:

The Association of Plastic Recyclers (APR) contracted with Franklin Associates, a division of Eastern Research Group (ERG), to examine the life cycle impacts of postconsumer recycled plastic pellets vs. virgin plastic pellets from petrochemical sources¹. This most recent study comparing plastic pellets is one of many over the last two decades and reflects current mechanical recycling practice. The study was for PET pellets (solid state polymerized as used for drink bottles), high density polyethylene (HDPE) pellets and polypropylene (PP) pellets.

Franklin Associates is a well-recognized life cycle study practitioner. Franklin Associates has been contracted by the US EPA for many years to conduct municipal solid waste studies. Franklin Associates has conducted life cycle inventories, LCIs, since before the discipline of life cycle assessment was formally defined by ISO and SEATAC; Franklin Associates was instrumental in the formalizing of the discipline. Franklin Associates is a regular contributor to and supporter of the United States Life Cycle Inventory Database (US LCI Database), maintained at the National Renewable Energy Laboratory, NREL. Franklin Associates followed ISO 14000 standards in the conduct of this study.

¹ December 2018, **LIFE CYCLE IMPACTS FOR POSTCONSUMER RECYCLED RESINS: PET, HDPE, AND PP** <https://plasticsrecycling.org/images/apr/2018-APR-Recycled-Resin-Report.pdf>

The December 2018 report includes 2018 values for recycled plastics and the then most current virgin plastics numbers from 2011². Since then, NAPCOR has issued another Franklin Associates study on virgin PET which shows significant improvements in both expended energy and greenhouse gas emissions compared to the virgin PET values from 2011.

The scope of the 2018 study begins with extraction of petroleum and natural gas for virgin plastic resins or begins with collection from the consumer for postconsumer recycled plastic and ends with pellets, ready for molding into packaging or other uses. Electricity and petroleum data are drawn from public sources including the US LCI Database. The calculations are for 100% virgin and 100% recycled pellets. Packaging was not made for this comparison. The results are shown below:

| Plastic Pellet Life Cycle Energy and Global Warming Potential, Virgin vs. Recycled, PET, HDPE, and PP¹ | | | | | |
|--|--------------------------------|---------------------------------|------------------------------------|------------------------------------|---|
| | | Total Energy <u>MJ/Kg</u> | Expended Energy <u>MJ/Kg</u> | Inherent Energy <u>MJ/Kg</u> | Global Warming Potential <u>Kg CO₂E/Kg</u> |
| PET | 100% Virgin Resin ³ | 61.4 | 24.5 | 36.9 | 2.23 |
| | 100% Recycled Resin | 14.8 | 14.8 | 0 | 0.91 |
| | Recycled/Virgin, % | 24% | 60% | | 41% |
| | Virgin/Recycled Ratio | 4.1 | 1.7 | | 2.5 |
| HDPE | 100% Virgin Resin | 75.3 | 25.9 | 49.4 | 1.89 |
| | 100% Recycled Resin | 8.7 | 8.7 | 0 | 0.56 |
| | Recycled/Virgin, % | 12% | 34% | | 30% |
| | Virgin/Recycled Ratio | 8.7 | 3.0 | | 3.4 |
| PP | 100% Virgin Resin | 74.4 | 26.3 | 48.1 | 1.84 |
| | 100% Recycled Resin | 8.9 | 8.9 | 0 | 0.53 |
| | Recycled/Virgin, % | 12% | 34% | | 29% |
| | Virgin/Recycled Ratio | 8.4 | 3.0 | | 3.5 |

¹ Source: December 2018, **LIFE CYCLE IMPACTS FOR POSTCONSUMER RECYCLED RESINS: PET, HDPE, AND PP**. Recycled resin values for 2018, virgin HDPE and PP resin values for 2011.

³ A 2020 revision, released to the US LCI Database by the National Association for PET Container Resources (NAPCOR), lowers the virgin PET total energy to 61.4 MJ/Kg (a 12% improvement due to process improvement) and Global Warming Potential to 2.23 Kg CO₂E/Kg (an 18% improvement over 2011 value due to substitution of natural gas for coal for grid electricity and process improvement). The data will publish on the US LCI Database in June 2020. Franklin Associates conducted the study.

² August 2011, **CRADLE-TO-GATE LIFE CYCLE INVENTORY OF NINE PLASTIC RESINS AND FOUR POLYURETHANE PRECURSORS**, <https://plastics.americanchemistry.com/LifeCycle-Inventory-of-9-Plastics-Resins-and-4-Polyurethane-Precursors-Rpt-Only/>

An update for virgin HDPE and virgin PP resin pellets is being planned, but will not be available soon. One should note that the ‘Virgin/Recycled Ratio’ that exceeds 1.0 means greater environmental burden for virgin resin pellets than for recycled resin pellets. For total energy, expended energy, and global warming potential (commonly called greenhouse gas, GHG profile, or ‘carbon footprint’) recycled plastic creates less burden than does virgin plastic for each of the three resins investigated when examining the different routes to make plastic pellets, the starting point to make consumer goods.

The following table is from December 2018 report, LIFE CYCLE IMPACTS FOR POSTCONSUMER RECYCLED RESINS: PET, HDPE, AND PP, Table 3-9. It summarizes the comparison of environmental impacts to make plastic pellets from petrochemical sources or from postconsumer collection of used items.

Table 3-9

Savings for Recycled Plastic Resins Compared to Virgin Plastic Resins¹

| | Recycled PET | | Recycled HDPE | | Recycled PP | |
|--------------------------|-----------------------------------|---|-----------------------------------|---|-----------------------------------|---|
| | Recycled % of <u>Virgin</u> | Recycled Resin % Reduction <u>from Virgin²</u> | Recycled % of <u>Virgin</u> | Recycled Resin % Reduction <u>from Virgin</u> | Recycled % of <u>Virgin</u> | Recycled Resin % Reduction <u>from Virgin</u> |
| | Total Energy | 21% | 79% | 12% | 88% | 12% |
| Water Consumption | 104% | -4% | 41% | 59% | 54% | 46% |
| Solid Waste ³ | 42% | 58% | 101% | -1% | 77% | 23% |
| Global Warming Potential | 33% | 67% | 29% | 71% | 29% | 71% |
| Acidification | 30% | 70% | 53% | 47% | 42% | 58% |
| Eutrophication | 54% | 46% | 102% | -2% | 57% | 43% |
| Smog | 25% | 75% | 63% | 37% | 50% | 50% |

¹ The Cut-Off assumption is used. All initial burdens are assigned to first use, not allocated to recycle use. December 2018, LIFE CYCLE IMPACTS FOR POSTCONSUMER RECYCLED RESINS: PET, HDPE, AND PP <https://plasticsrecycling.org/images/apr/2018-APR-Recycled-Resin-Report.pdf>

² The comparison cited here are from the December 2018 study and do not reflect the improvements for virgin PET in the 2020 Franklin Associates report done for NAPCOR

³ Solid waste excluding contaminants removed from incoming material. These contaminants are not caused by recycling and would have been disposed as waste regardless of whether postconsumer plastic recycling

One should remember that while ‘eternal recycling’ is a philosophical goal, the laws of thermodynamics teach that eternal recycling is like perpetual motion and cannot be achieved. Virgin material is always needed.

While the cited Franklin Associates reports do not discuss statistical significance, in the past Franklin Associates has argued that statistical significance requires a 10% difference in results. On that basis PET water consumption, virgin or recycled resin, is the same as is the solid waste for HDPE and eutrophication burdens for virgin or recycled HDPE.