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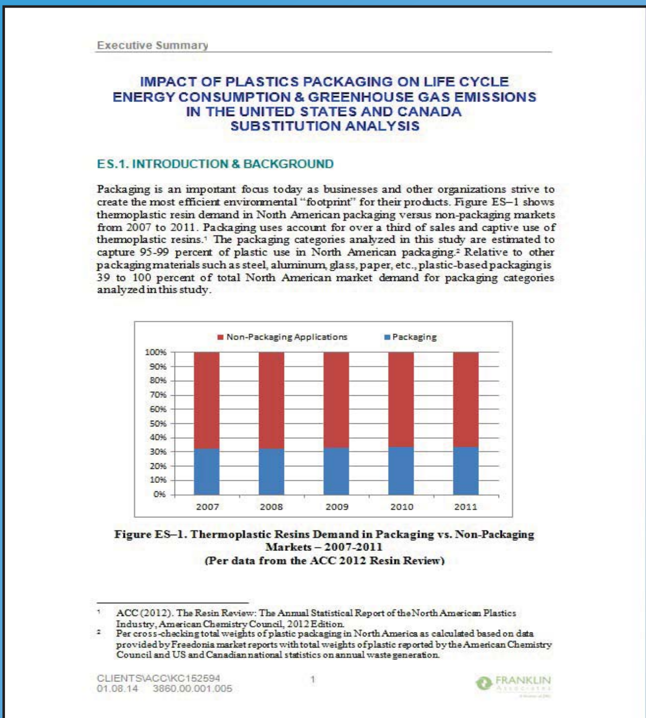

Executive Summary

IMPACT OF PLASTICS PACKAGING ON LIFE CYCLE ENERGY CONSUMPTION & GREENHOUSE GAS EMISSIONS IN THE UNITED STATES AND CANADA SUBSTITUTION ANALYSIS

ES.1. INTRODUCTION & BACKGROUND

Packaging is an important focus today as businesses and other organizations strive to create the most efficient environmental "footprint" for their products. Figure ES–1 shows thermoplastic resin demand in North American packaging versus non-packaging markets from 2007 to 2011. Packaging uses account for over a third of sales and captive use of thermoplastic resins.[1] The packaging categories analyzed in this study are estimated to capture 95-99 percent of plastic use in North American packaging.[2] Relative to other packaging materials such as steel, aluminum, glass, paper, etc., plastic-based packaging is 39 to 100 percent of total North American market demand for packaging categories analyzed in this study.

Non-Packaging Applications
Packaging
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2007
2008
2009
2010
2011

Figure ES–1. Thermoplastic Resins Demand in Packaging vs. Non-Packaging Markets – 2007-2011 (Per data from the ACC 2012 Resin Review)

1 ACC (2012). The Resin Review: The Annual Statistical Report of the North American Plastics Industry, American Chemistry Council, 2012 Edition.

2 Per cross-checking total weights of plastic packaging in North America as calculated based on data provided by Freedonia market reports with total weights of plastic reported by the American Chemistry Council and US and Canadian national statistics on annual waste generation.

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EXECUTIVE SUMMARY
IMPACT OF PLASTICS PACKAGING ON LIFE CYCLE ENERGY CONSUMPTION & GREENHOUSE GAS EMISSIONS IN THE UNITED STATES AND CANADA
Substitution Analysis

PREPARED FOR

The American Chemistry Council (ACC) and The Canadian Plastics Industry Association (CPIA)

BY

Franklin Associates, A Division of Eastern Research Group (ERG) January 2014

January 2014

Preface

This work was conducted for The American Chemistry Council (ACC) and the Canadian Plastics Industry Association (CPIA) under the direction of Mike Levy for ACC, Cathy Cirko and Fred Edgecombe for CPIA, and Ashley Carlson of Ashley Carlson Consulting. We gratefully acknowledge their assistance in the development of this report.

At Franklin Associates, the project was managed by Beverly Sauer, Senior Chemical Engineer and Project Manager, who served as reviewer of the substitution model and report, as well as assisting with modeling and write up of results. Rebe Feraldi was the lead in developing the substitution model and write up and conducted the majority of the modeling with assistance from Janet Mosley. Shelly Schneider and Anne Marie Molen assisted with research tasks and development of the report. Lori Snook contributed to report preparation tasks.

Franklin Associates gratefully acknowledges significant contributions to this project by external reviewers Harald Pilz of Denkstatt GmbH and Roland Hischier of the Empa Research Institute. Revisions made in response to their review comments improved the quality and transparency of the report.

The work was performed by Franklin Associates, A Division of ERG as an independent contractor. The findings and conclusions are strictly those of Franklin Associates acting in this role. Franklin Associates makes no statements nor supports any conclusions other than those presented in this report.

January 2014

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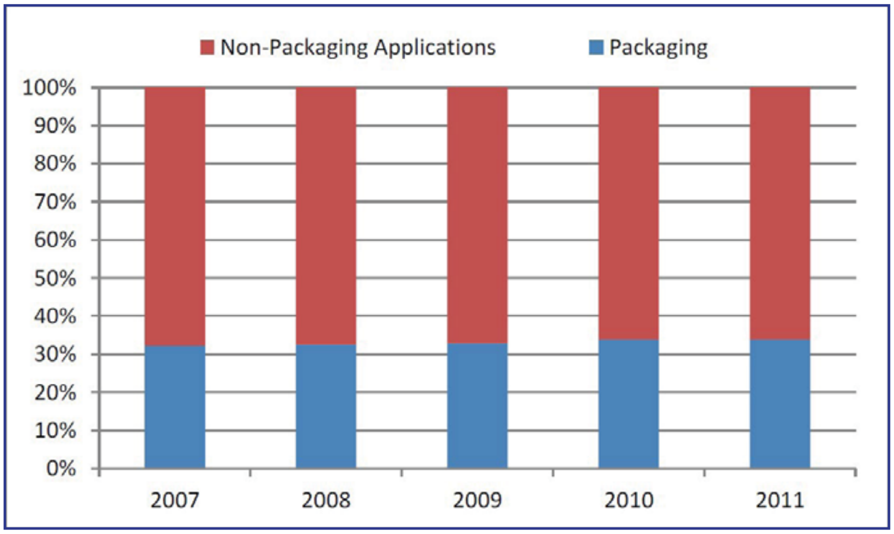
IMPACT OF PLASTICS PACKAGING ON LIFE CYCLE ENERGY CONSUMPTION & GREENHOUSE GAS EMISSIONS IN THE UNITED STATES AND CANADA SUBSTITUTION ANALYSIS

ES.1. INTRODUCTION & BACKGROUND

Packaging is an important focus today as businesses and other organizations strive to create the most efficient environmental "footprint" for their products. Figure ES–1 shows thermoplastic resin demand in North American packaging versus non-packaging markets from 2007 to 2011. Packaging uses account for over a third of sales and captive use of thermoplastic resins. [1] The packaging categories analyzed in this study are estimated to capture 95-99 percent of plastic use in North American packaging. [2] Relative to other packaging materials such as steel, aluminum, glass, paper, etc., plastic-based packaging is 39 to 100 percent of total North American market demand for packaging categories analyzed in this study.



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2. Per cross-checking total weights of plastic packaging in North America as calculated based on data provided by Freedonia market reports with total weights of plastic reported by the American Chemistry Council and US and Canadian national statistics on annual waste generation.

Executive Summary

The goal of the substitution analysis presented in this report is to use LCA methodology to assess the energy consumption and greenhouse gas (GHG) emissions of plastics packaging relative to alternative packaging in North America and answer the question: "If plastic packaging were replaced with alternative types of packaging, how would energy consumption and greenhouse gas emissions be affected?"

Commissioned by The American Chemistry Council (ACC) and the Canadian Plastics Industry Association (CPIA), Franklin Associates, A Division of ERG (hereinafter referred to as Franklin Associates) conducted this study of plastic packaging substitution for predominant packaging resins. The impacts of the current amounts of plastic packaging products were compared to a scenario in which plastic packaging is substituted by alternative materials (e.g., paper and paperboard, glass, steel, aluminum, textiles, rubber, and cork). All of the plastic resins investigated in this study are modeled to be sourced from fossil fuels (i.e., natural gas and petroleum). Though there have been recent developments in the production of biomass-based plastic resin, the market shares of these materials is not yet sufficient to warrant analyzing their substitution with other materials.

The geographic scope of this study is for packaging materials of the selected applications produced and sold in the US and Canada. The boundaries for this study incorporate raw material extraction through production of the packaging materials, their distribution, and their end-of-life management. This study examines greenhouse gas (GHG) emissions and energy demand.

This analysis was conducted to provide ACC and CPIA with transparent, detailed Life Cycle Assessment (LCA) results serving several purposes:

1. To provide stakeholders with valuable information about the relative life cycle energy and greenhouse gas impacts of plastic packaging and alternative packaging materials that might be used to substitute for plastic packaging in applications in the US and Canada,
2. To communicate plastics packaging sustainability information, important for purchasing and procurement, to ACC and CPIA customers and their value chain, and
3. To provide the North American market with key regional data for plastic packaging to show plastics' contribution to sustainable development.

The results of the substitution analysis in this report are not intended to be used as the basis for comparative environmental claims or purchasing decisions for specific packaging products, but rather are intended to provide a snapshot of the energy and GHG impacts of the current overall mix of plastic packaging in several categories, and the energy and GHG impacts of the overall mix of alternative types of packaging that might be used as substitutes. While this study examines packaging impacts using a life cycle approach, the study is limited to an assessment of energy and GHG impacts and does not include an expanded set of environmental indicators. Because the study assesses only energy and GHG impacts, and because the study is not intended for use in making comparative environmental claims about specific packaging products, the substitution analysis does not meet the ISO 14044 criteria for requiring a panel peer review

ES.2. METHODOLOGY

The LCA method as defined in ISO standards has four distinct phases:

1. ***Goal and scope definition:*** defines the boundaries of the product system to be examined.
2. ***Life Cycle Inventory (LCI)***: examines the sequence of steps in the life cycle boundaries of the product system, beginning with raw material extraction and continuing on through material production, product fabrication, use, and reuse or recycling where applicable, and final disposition. For each life cycle step, the inventory identifies and quantifies the material inputs, energy consumption, and environmental emissions (atmospheric emissions, waterborne wastes, and solid wastes). In other words, the LCI is the quantitative environmental profile of a product system. Substances from the LCI are organized into air, soil, and water emissions or solid waste.
3. ***Life Cycle Impact Assessment (LCIA):*** characterizes the results of the LCI into categories of environmental problems or damages based on the substance's relative strength of impact. Characterization models are applied to convert masses of substances from the LCI results into common equivalents of one category indicator.
4. ***Interpretation:*** uses the information from the LCI and LCIA to compare product systems, rank processes, and/or pinpoint areas (e.g., material components or processes) where changes would be most beneficial in terms of reduced environmental impacts. The information from this type of assessment is increasingly used as a decision-support tool.

This study has been conducted with an LCA approach as defined in ISO standards 14040 through 14044. Two LCA experts familiar with packaging analyses reviewed the details of the substitution analysis to ensure that the approach was reasonable and that the data sources and assumptions used were robust. The results presented in this report are specific to the US and Canadian geographic context and should not be interpreted as representing current or future plastic packaging substitution in other geographic areas. The following sections discuss the specifics of this methodology as applied in this study.

ES.2.1. Functional Unit

In any life cycle study, products are compared on the basis of providing the same defined function or unit of service (called the functional unit). This study uses a modeling approach to account for the standard LCI basis of product functionality for packaging materials. The general functional unit of the overall study is the substitution of total consumption of plastic used in each packaging category for the data year in which the most recent market data is available. Because the function of plastic packaging products differs amongst the investigated packaging categories, the functional unit is unique for each packaging category. The following Table ES–1 summarizes the functional unit considered for each packaging category.

Table ES–1. Functional Unit of Comparison for Investigated Packaging Categories

Category:	Functional Unit of Comparison for Alternative Material Weight Required:
Other Rigid	Volume Capacity for Non-Bulk & Bulk Rigid Packaging
	Protective Performance for Protective Packaging
Other Flexible	Volume Capacity for Converted & Bulk Packaging (except strapping)
	Protective Performance for Protective Packaging
	Unitizing Performance for Flexible Bulk Strapping
Beverage Containers	Volume Capacity
Carrier Bags	Number of Units (adjusted for difference in capacity)
Stretch & Shrink	Square Footage adjusted for performance
Caps & Closures	Number of Units

ES.2.2. Product Systems Studied

In 2010, packaging accounted for over a third of the major markets sales and captive use of thermoplastic resins in North America.3 The types of plastic packaging evaluated in the analysis are limited to the predominant packaging resins:

- Low-Density Polyethylene (LDPE)
- High-Density Polyethylene (HDPE)
- Polypropylene (PP)
- Polyvinyl Chloride (PVC)
- Polystyrene (PS)
- Expanded Polystyrene (EPS)
- Polyethylene Terephthalate (PET)

Other resins, including specialty copolymers, biopolymers, etc. are not included. This scope keeps the analysis focused on resins that represent the largest share of plastic packaging and for which data are readily available.

Alternative materials that substitute the plastic packaging include: steel; aluminum; glass; paper-based packaging including corrugated board, packaging paper, cardboard (both coated and uncoated), molded fiber, paper-based composites and laminates; fiber-based textiles; and wood. Substitutes for plastic packaging vary depending on the market sector and packaging application. Cork and rubber are included as substitutes only in the caps and closures category.

3. ACC (2012). The Resin Review: The Annual Statistical Report of the North American Plastics Industry, American Chemistry Council, 2012 Edition.

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This LCA focuses on plastic packaging applications and the plastic materials which are substitutable by alternative materials. The packaging sector is divided into the following categories of case studies presented in descending order of plastic packaging weight, e.g., from highest to lowest percent share of the total weight of current plastic packaging:

- Other rigid packaging (includes the subcategories non-bulk rigid packaging, rigid protective packaging, and rigid bulk packaging)
- Other flexible packaging (includes the subcategories converted flexible packaging, flexible protective packaging, and flexible bulk packaging)
- Beverage packaging
- Carrier bags
- Shrink and stretch film
- Caps and closures

The following life cycle stages are included for each packaging material application:

1. **Raw material production** of the packaging materials, which consists of all steps from resource extraction through raw material production, including all transportation,
2. **Fabrication of the packaging** from their raw materials and the subsequent transportation of empty packaging from the fabrication site to the commodity filling site,
3. **Distribution transport** of commodity and packaging from the commodity filling site to a the use site (focusing on differences in impacts due to packaging itself),
4. **Postconsumer** disposal of packaging in a landfill or waste-to-energy incineration, and/or
5. **Recycling** of packaging, including transport from the use site to recycling facilities, where applicable.

If the plastic packaging for a specific packaging application is made of more than one polymer, the market shares of the relevant polymers are considered. Likewise, if more than one alternative packaging material could substitute the analyzed plastic packaging, the national market shares of these materials is included in the calculations. The analysis focuses on the primary material components of each package and does not include small amounts of substances such as adhesives, labels, and inks.

The boundaries account for transportation requirements between all life cycle stages. Because of the very broad scope of packaging products covered by the project, some broad simplifying assumptions have been made regarding transportation distances and modes for shipping packaging from converters to fillers in both the US and Canada. For the production of electricity used in US packaging production and converting operations, the US average electricity grid mix is used.[4] For production of electricity used in

4. The exception is for the primary aluminum supply chain, which is modeled with the electricity grids of its corresponding geographies (including Australia and Jamaica).

Continued......

Executive Summary

Canadian packaging production and converting operations, the average Canadian electricity grid mix is used. [5]

Filling requirements for the products contained in the investigated packaging applications are excluded from the boundaries of this study as they are beyond the scope of this study. Storage, refrigeration, and/or freezing requirements as well as the burdens associated with the product use phase are considered equivalent between directly substituted packaging materials and so are excluded from the analysis. This analysis is based on the amounts and types of substitutes that would provide equivalent functionality to plastic packaging and therefore does not attempt to evaluate differences in product damage associated with use of different packaging materials.

For the average US or Canadian geographic context, average recycling rates and pathways for packaging used in the analyzed applications have been developed from research, recent publications, and previous work conducted by Franklin Associates. For the US geographic scope, postconsumer disposal of the percentage of packaging not recycled is modeled with current US EPA statistics for waste management. [6] For the Canadian geographic scope, average recycling rates and pathways for packaging used in Canada are modeled with current Canadian national waste management statistics. [7]
Franklin Associates uses the system expansion end-of-life (EOL) recycling methodology to account for changes in life cycle burdens due to the recycling of packaging materials and the use of recycled material in packaging products.

A summary flow diagram of the boundaries for the packaging applications is shown in Figure ES–2. These boundaries are identical for either the US or Canadian geographic scope.

5. IEA (2010). Electricity/Heat in Canada in 2009, International Energy Agency, Available at: http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=CA
6. US Environmental Protection Agency. Municipal Solid Waste Generation, Recycling, and Disposal in the United States, see: http://www.epa.gov/wastes/nonhaz/municipal/msw99.htm
7. Statistics Canada (2012). Human Activity and the Environment: Waste Management in Canada, 2012

– Updated, Statistique Canada, Catalogue no. 16-201-X, Ministry of Industry, September 2012

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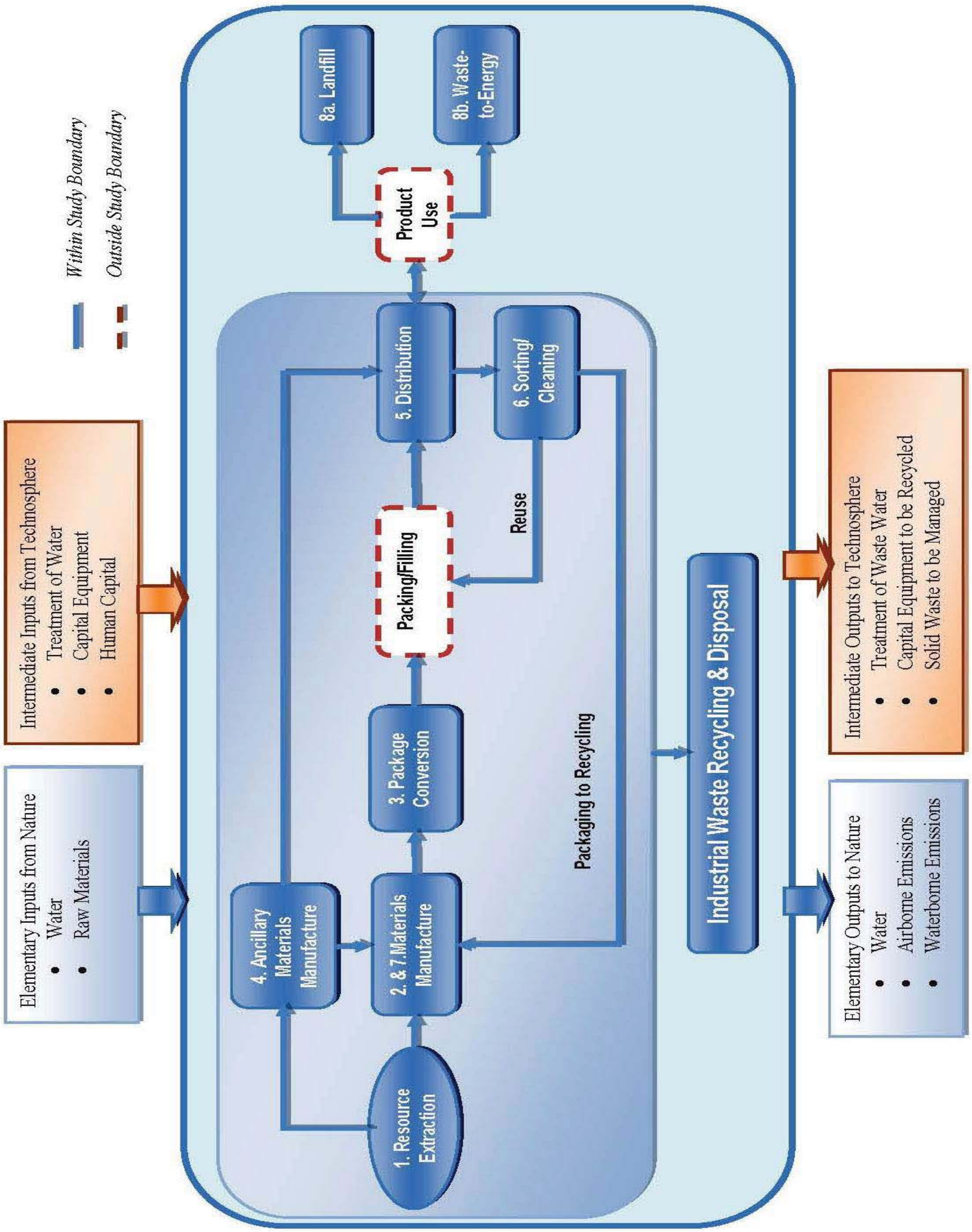


Figure ES–2. Packaging Products System Boundaries

ES.2.3. Data Sources

The primary source of market data (i.e., market shares of packaging product applications by type and by material) for packaging materials in the US and Canada were from Freedonia Market Reports for data years 2007-2011 and from the ACC 2012 Resins Review. [8] These data along with public and private LCA and packaging case studies and assumptions made by Franklin Associates were used to compile the weight factors for non-plastic materials to substitute for plastic packaging resins. To model the life cycle impacts of plastic versus non-plastic packaging materials, Franklin Associates uses the most current North American life cycle data on materials and fuels used in each system. Data transparency is important, so wherever possible we have used data from publicly available sources, such as the US LCI Database. [9] For unit processes for which public data were not available, Franklin Associates has clearly cited the private data sources and disclosed as much information as possible without compromising the confidentiality of the data source. For example, where data from the ecoinvent database are used, Franklin Associates has adapted the data so it is consistent with other North American data modules used in the study and representative of the energy production and transportation. [10]

ES.2.4. Reuse & Recycling Modeling Approach

In this study, national reuse and recycling rates for the packaging product type and/or material are applied for the US and Canadian geographic scopes. When material is used in one system and subsequently recovered, reprocessed, and used in another application, there are different methods that can be used to allocate environmental burdens among different useful lives of the material.

In this study, burdens associated with recycled content of products include collection, transport, and reprocessing of the postconsumer material. None of the virgin production burdens for the material are allocated to its secondary use(s).

For packaging material that is recycled at end of life, the recycling of packaging materials is modeled as a mix of closed- and open-loop recycling, as appropriate for each

8. ACC (2012). The Resin Review: The Annual Statistical Report of the North American Plastics Industry, American Chemistry Council, 2012 Edition.
9. National Renewable Energy Lab (NREL). US LCI Database. See: http://www.nrel.gov/lci/database/default.asp
10. In addition to data developed specifically for North American processes and materials, Franklin Associates has an LCI database of materials and processes adapted from the ecoinvent LCI Database for the North American context. The database generally contains materials and processes specific to commodities sold in North America for which U.S. LCI data are not currently available. To adapt the LCI processes to the North American geographic context, most of the following (foreground and background) material and fuel unit processes within the European module were substituted with those inventoried in North America: 1) transport processes, 2) fossil fuels extraction, processing, and combustion, 3) mineral and metals extraction and fabrication processes, 4) plastic resin production and plastics fabrication processes, 5) paper and paperboard products production , 6) organic chemicals production, and 7) inorganic chemicals production.

packaging application and/or material. System expansion is the approach used to avoid allocation in this analysis. Under the system expansion approach, the types and quantities of materials that are displaced by the recovered post-consumer material determine the types and quantities of avoided environmental material production credits. If the end-of- life recycling rate is higher than the recycled content of the product, the system is a net producer of material, so the system receives open-loop credit for avoiding production of virgin material equivalent to the amount of end-of-life recycling that exceeds the system's recycled content. Conversely, if the end-of-life recycling rate is lower than the recycled content of the product, then the system is a net consumer of material and is charged with burdens for the production of material needed to make up the deficit.

ES.2.5. Key Assumptions

Although the foreground processes in this analysis were populated with reliable market data and the background processes come from reliable LCI databases, most analyses still have limitations. Further, it is necessary to make a number of assumptions when modeling, which could influence the final results of a study. Key limitations and assumptions of this analysis are:

- Because of the large scope of this study, this analysis uses the LCA approach to identify overall trends in the GWP and energy demand of packaging categories rather than performing a detailed LCA on hundreds of packaging products for individual applications;
- The study is limited to GWP and energy results for plastic and non-plastic substitute packaging; other impact categories such as water consumption and abiotic resource depletion are not included in the analysis
- For each plastic packaging category, the current market share of plastic resins determines the weight of replaced resin. The weight of replaced resin is multiplied by the substitute material-to-plastic weight ratio calculated for each packaging application (based on functional equivalency to the representative plastic packaging product) to provide the weight of alternative material projected to substitute for the plastic package.
- For the substitutions, it is assumed that the product contained/unitized by the packaging would not be changed or altered in any way (e.g., a rigid plastic container for liquid soap must be substituted by another rigid container designed for liquids rather than projecting that the weight of a paperboard box designed for powdered soap may substitute for the plastic container)
- For each geographic scope, all foreground processes are assumed to utilize the national average electricity grid fuel mix; the exception is for the primary aluminum supply chain. The electricity grids for each aluminum production step from bauxite mining through alumina production are modeled based on the mix of geographies (including Australia and Jamaica) where each production step takes place.

- LCI requirements for filling, storage, freezing, refrigeration, product manufacturing, capital equipment, and support personnel as well as differences in product damage in various packaging materials are excluded from the analysis
- Transportation requirements inventoried for specific transportation modes are based on industry averages for that mode for each country;
- Transportation requirements do not include environmental burdens for transporting the weight of the products contained by the packaging as this weight is equivalent between the packaging materials/types and the life cycle burdens of the contained products are outside the scope of this study;
- For each geographic scope, estimates of the end results of landfilling and waste- to-energy (WTE) combustion are limited to global warming potential (GWP) effects, electricity credits, and requirements for transporting waste to a landfill and operating landfill equipment. Recycling energy requirements are also taken into account, and include transportation and reprocessing of the material as well as credit for virgin material displaced by the recycled material.

ES.3. KEY FINDINGS

The LCI results are characterized to give an overview of comparative global warming potential (GWP) and energy results for plastic and alternative material packaging systems. Two categories of energy results are reported: cumulative energy demand (CED) and expended energy. Cumulative energy demand includes all fossil and non- fossil energy expended as process energy and transportation energy, as well as the feedstock energy embodied in the packaging material. Expended energy excludes the energy embodied in the packaging material. This distinction is relevant for plastics, because embodied feedstock energy is still potentially available for future use (e.g., via material recycling or material combustion with energy recovery). Because plastics use fossil fuels as material feedstocks, a high percentage of CED for plastic packaging is feedstock energy.

Two scenarios are analyzed for substitute packaging. The “no decomposition” scenario includes biogenic CO2 sequestration credit for all the biogenic carbon in landfilled packaging (i.e., no decomposition over time of any landfilled biomass-derived packaging), while the “maximum decomposition” scenario is based on maximum decomposition of uncoated paper and paperboard packaging that is disposed in landfills. For coated/laminated paper and paperboard products, the barrier layers are assumed to minimize any decomposition of the fiber content; therefore, to use a conservative approach, no decomposition of the fiber content of coated/laminated paper-based packaging is modeled in either decomposition scenario.

Global warming potential is characterized using factors reported by the Intergovernmental Panel on Climate Change (IPCC) in 2007. Energy demand results are assessed with Franklin Associates’ customized method based on the CED method available in SimaPro software, adapted for North American energy flows. The results for GWP are expressed in units of carbon dioxide (CO2) equivalents. All of the results for energy demand are expressed in units of mega joule (MJ) equivalents.

Chapter 4. GWP & Energy Results for Packaging Systems

Table ES–2 and Table ES–3 present results representing the savings for plastics versus alternative material packaging at the US and Canadian national demand levels, respectively. Comparative GWP and CED results for categories of packaging within each geographic scope are shown in Figure ES–3 and Figure ES–4 for US packaging and in Figure ES–5 and Figure ES–6 for Canada.

Table ES–2. Savings for Plastic Packaging Compared to Substitutes – US Scope

	Savings for Plastic Packaging Relative to Substitute Packaging, by Category, US					
	Global Warming Potential (million metric tonnes CO2 eq)		Cumulative Energy Demand (billion MJ)		Expended Energy (billion MJ)	
	No Decomp	Maximum Decomp	No Decomp	Maximum Decomp	No Decomp	Maximum Decomp
Caps & Closures	(0.28)	(0.05)	(38.8)	(39.0)	(1.53)	(1.68)
Beverage Containers	9.70	9.60	118	117	204	203
Stretch & Shrink	10.5	11.1	180	178	161	159
Carrier Bags	8.65	10.6	72.6	71.4	123	122
Other Flexible	26.8	37.7	725	714	651	640
Other Rigid	20.4	20.7	52.7	52.3	236	235
Total	**75.8**	**89.6**	**1,110**	**1,093**	**1,373**	**1,357**

Table ES–2. Savings for Plastic Packaging Compared to Substitutes – Canadian Scope

	Savings for Plastic Packaging Relative to Substitute Packaging, by Category, Canada					
	Global Warming Potential (million metric tonnes CO2 eq)		Cumulative Energy Demand (billion MJ)		Expended Energy (billion MJ)	
	No Decomp	Maximum Decomp	No Decomp	Maximum Decomp	No Decomp	Maximum Decomp
Caps & Closures	0.0011	0.018	(3.30)	(3.32)	(0.23)	(0.25)
Beverage Containers	0.47	0.43	8.27	7.81	14.9	14.5
Stretch & Shrink	2.34	2.40	35.1	34.2	33.0	32.1
Carrier Bags	3.70	3.99	43.9	43.4	48.6	48.1
Other Flexible	4.72	6.43	101	96.5	94.3	89.5
Other Rigid	4.55	4.59	35.8	35.6	55.8	55.6
Total	**15.8**	**17.9**	**221**	**214**	**246**	**240**

Chapter 4. GWP & Energy Results for Packaging Systems

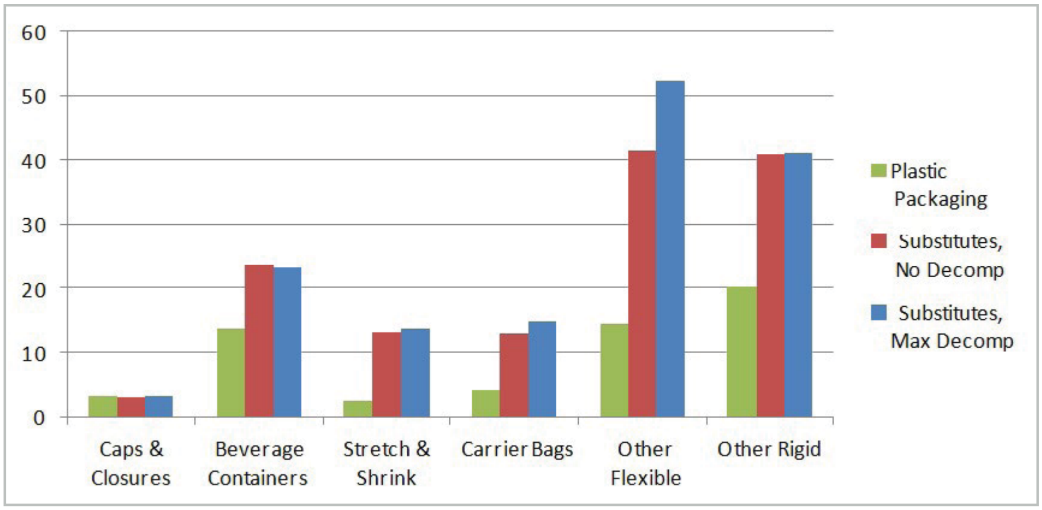


Figure ES–3. GWP Results by Category for US Plastic Packaging and Substitutes (million metric tonnes CO_2 eq)

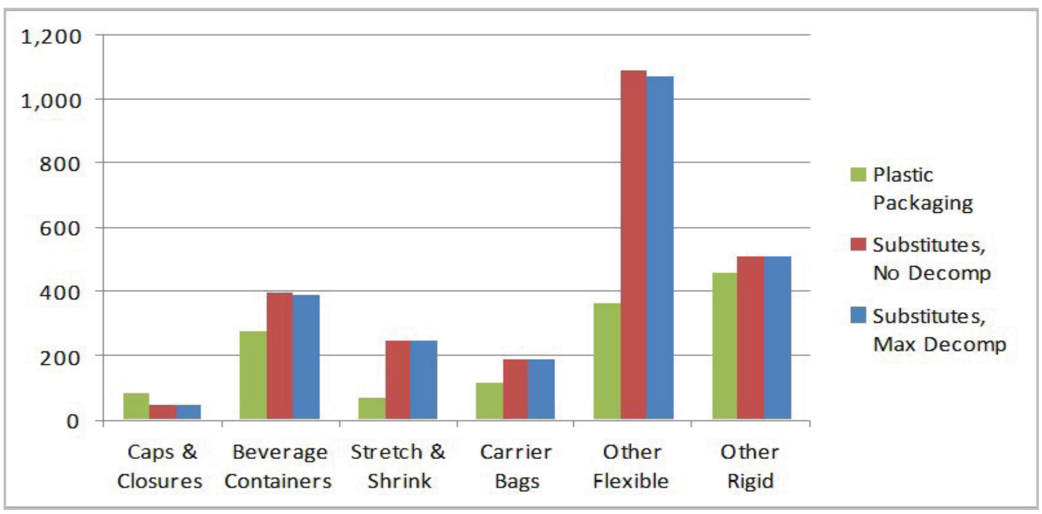
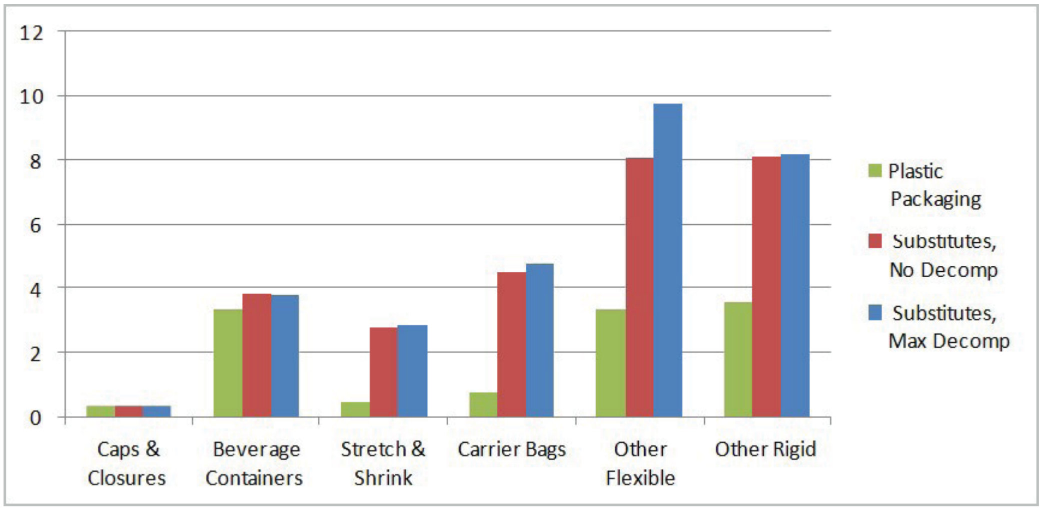


Figure ES–4. CED Results by Category for US Plastic Packaging and Substitutes (billion MJ)

Chapter 4. GWP & Energy Results for Packaging Systems



F igure ES–5. GWP Results by Category for Canadian Plastic Packaging and Substitutes (million metric tonnes CO_2 eq)

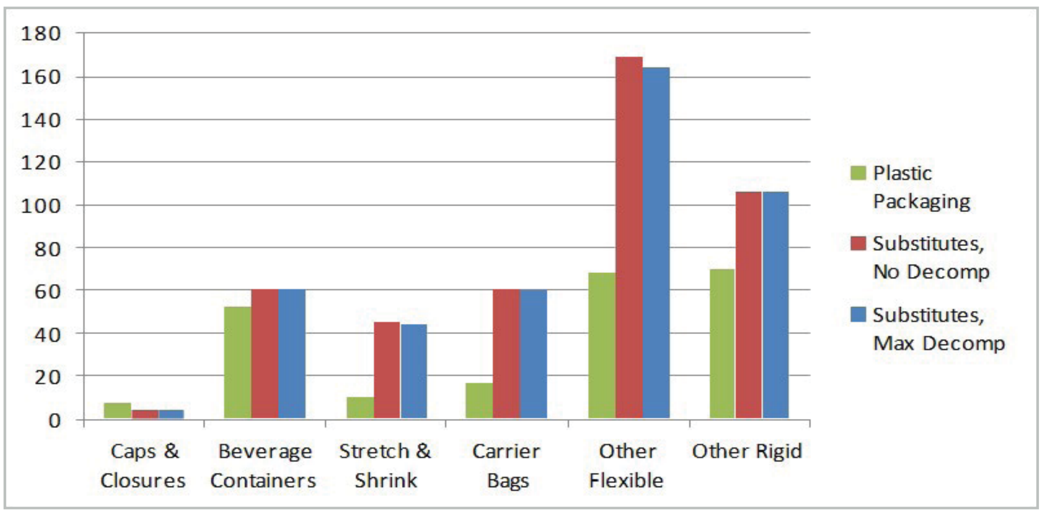


Figure ES–6. CED Results by Category for Canadian Plastic Packaging and Substitutes (billion MJ)

For US packaging, Table ES–2 shows that GWP savings are 75.8 million metric tonnes CO_2 eq for plastic packaging compared to the minimum decomposition scenario for substitute packaging results. The corresponding energy savings for plastic packaging compared to substitute packaging with minimum decomposition, also shown in Table ES-2, are CED savings of 1,110 billion MJ and expended energy savings of 1,373 billion MJ.

Chapter 4. GWP & Energy Results for Packaging Systems

Although expended energy is a subset of CED, the expended energy savings are greater than CED savings. Feedstock energy is a much greater share of CED for plastics compared to substitutes; therefore, the difference in expended energy (CED minus feedstock energy) for plastics compared to substitutes is greater than the difference in CED results. The maximum decomposition scenario for substitutes has higher GWP results due to methane emissions from landfill decomposition of some of the paper-based packaging, so the GWP savings for plastics are greater in the maximum decomposition scenario. However, the energy savings for plastics are slightly smaller in the maximum decomposition scenario. This is because the maximum decomposition scenario for substitutes includes some energy credits for energy recovered from combustion of captured landfill gas from paper-based substitute packaging that decomposes.

Canadian savings for plastic packaging compared to substitutes, shown in Table ES–3, are also significant. Savings for plastic packaging compared to the minimum decomposition scenario for substitute packaging are 15.8 million metric tonnes CO_2 eq, CED savings of 221 billion MJ, and expended energy savings of 246 billion MJ. Savings for plastic packaging compared to the maximum decomposition scenario for substitute packaging are 17.9 million metric tonnes CO_2 eq, CED savings of 214 billion MJ, and expended energy savings of 240 billion MJ.

Because the magnitude of the savings results on these scales may be difficult to interpret, equivalency factors are used to provide perspective for the study results. The equivalency factors derived from the US EPA Greenhouse Gas Equivalencies Calculator11 are shown in Table ES–4. Table ES–5 and Table ES–6 show savings for the US and Canada, respectively. For the US, the "no decomposition" scenario GWP savings are equivalent to the annual GHG emissions from over 15 million passenger vehicles or 21 coal-fired power plants. The Canadian "no decomposition" GWP savings are equivalent to avoiding the emissions from burning 208,000 tanker trucks of gasoline or 68,000 railcars of coal. Additional equivalencies are shown at the bottom of Table ES–5 and Table ES–6.

The top sections of Table ES–5 and Table ES–6 show overall total greenhouse gas and energy results for plastic packaging and the two substitute packaging scenarios. Since the plastic packaging analyzed in this study does not decompose, plastic packaging results are shown under the "No Decomp" heading.

11. http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Continued......

Chapter 4. GWP & Energy Results for Packaging Systems

Table ES–4. Energy and Greenhouse Gas Equivalency Factors

Equivalency	Basis*	MJ	kg CO2 eq
Passenger vehicles per year	21.5 mpg, 11,493 miles traveled	70,495	4,841
Barrels of crude oil	42 gallons per barrel	6,119	432
Tanker truck of gas	8,500 gallons per tanker	1.12E+06	7.58E+04
Railcar of coal	90.89 metric tons coal per railcar	2.64E+06	2.33E+05
Coal-fired power plant emissions	1.6 billion metric tons CO_2 emitted by 457 coal-fired plants in 2009		3.53E+09
Oil supertanker	2 million barrels crude oil per tanker	1.22E+10	8.64E+08

*Detailed supporting calculations for the CO_2 equivalencies , including energy content and combustion emissions for each form of fuel , ca n be found a t http://www.epa .gov/clean energy /energy-resources /refs .html . Energy equivalencies were also calculated using information from this website. The oil supper tanker equivalencies are not found directly in the calculator but a re based on 2 million barrels per s upper tanker (from the America n Merchant Sea ma n's Manual), multiplied by the calculator results
for one barrel of crude oil.

Table ES–5. Savings for US Plastic Packaging Compared to Substitutes

	Comparison of Plastic Packaging and Substitute Packaging, US					
	Global Warming Potential (million metric c tonnes CO2 eq.)		Cumulative Energy Demand (billion MJ)		Expended Energy (billion MJ)	
	No Decomp	Max Decomp	No Decomp	Max Decomp	No Decomp	Max Decomp
Total for Plastic Packaging	58.6		1,357		703	
Total for Substitutes	134	148	2,466	2,450	2,076	2,060
Savings for Plastics	**75.8**	**89.6**	**1,110**	**1,093**	**1,373**	**1,357**
Substitutes % Higher than Plastics	129%	153%	82%	81%	195%	193%
Savings Equivalencies						
Million passenger vehicles per year	15.7	18.5	15.7	15.5	19.5	19.2
Million barrels of oil	176	207	181	179	224	222
Thousand tanker trucks of gasoline	1,000	1,182	990	976	1,225	1,210
Thousand railcars of coal	326	385	420	414	519	513
Coal-fired power plants (annual emissions)	21	25				
Oil super tankers	88	104	91	89	112	111

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Chapter 4. GWP & Energy Results for Packaging Systems

Table ES–6. Savings for Canadian Plastic Packaging Compared to Substitutes

	Comparison of Plastic Packaging and Substitute Packaging, Canada					
	Global Warming Potential (million metric tonnes CO2 eq.)		Cumulative Energy Demand (billion MJ)		Expended Energy (billion MJ)	
	No Decomp	Max Decomp	No Decomp	Max Decomp	No Decomp	Max Decomp
Total for Plastic Packaging	11.8		225		155	
Total for Substitutes	27.5	29.6	446	439	401	394
Savings for Plastics	**15.8**	**17.9**	**221**	**214**	**246**	**240**
Substitutes % Higher than Plastics	134%	152%	98%	95%	159%	155%
Savings Equivalencies						
Million passenger vehicles per year	3.3	3.7	3.1	3.0	3.5	3.4
Million barrels of oil	36.5	41.3	36.1	35.0	40.3	39.1
Thousand tanker trucks of gasoline	208	236	197	191	220	214
Thousand railcars of coal	68	77	84	81	93	91
Coal-fired power plants (annual emissions)	4.5	5.1				
Oil super tankers	18	21	18	18	20	20

Plastics have many properties that make them a popular choice in packaging applications. Properties such as light weight, durability, flexibility, cushioning, and barrier properties make plastic packaging ideally suited for efficiently containing and protecting many types of products during shipment and delivery to customers without leaks, spoilage, or other damage. The results of this substitution analysis show that plastic packaging is also an efficient packaging choice in terms of energy and global warming impacts.

- **On a US national level, to substitute the 14.4 million metric tonnes of plastic packaging in the six packaging categories analyzed, more than 64 million metric tonnes of other types of packaging would be required. The substitute packaging would require 80 percent more cumulative energy demand and result in 130 percent more global warming potential impacts, expressed as CO_2 equivalents, compared to the equivalent plastic packaging.**
- **On a Canadian national level, replacing the 1.6 million metric tonnes of plastic packaging would require more than 7.1 million metric tonnes of substitute packaging. Energy requirements for substitute packaging are twice as high as the equivalent plastic packaging, and global warming potential impacts for the substitute packaging are more than double the impacts for the plastic packaging replaced.**

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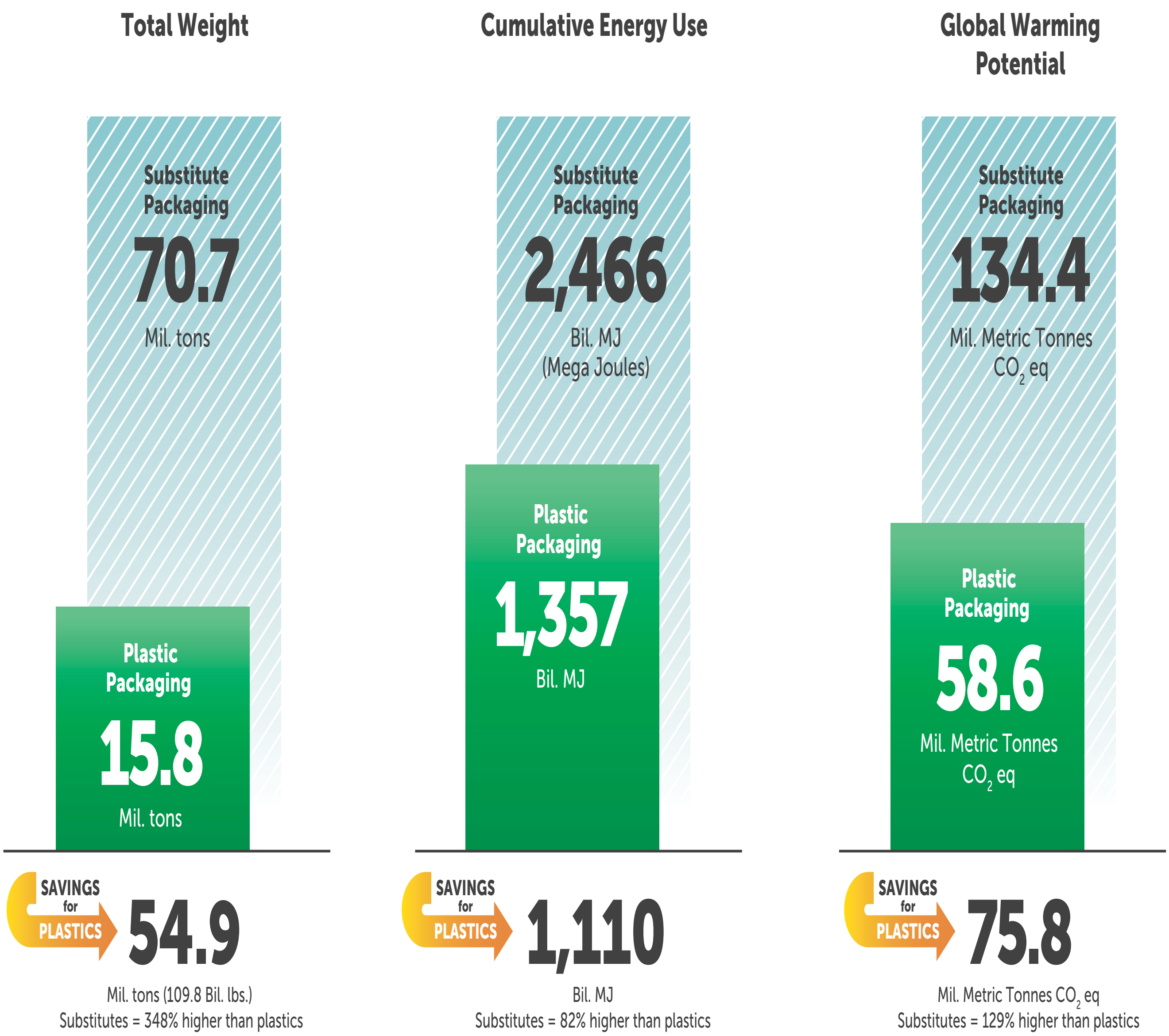
ICPE observation

Although geographic scope of this LCA study was the USA and Canada, however findings of the study holds good elsewhere in the world also, including India.

DATA SHEET

Common Plastics Packaging Helps Reduce Package Weight, Energy Use and GHG Emissions in U.S.



Source: "Impact of Plastics Packaging on Life Cycle Energy Consumption & Greenhouse Gas Emissions in the United States and Canada," Franklin Associates 2014. Study based on 2010 data.
This study measures energy use and GHG emissions and is not an ISO 14044 life cycle assessment.