**Technical assessment for**

**Recycled Plastics**

Sector: Industry

Agency Level: Producers

Keywords: Recycling, Plastics, Recycled Plastic, Circular Economy, Extractable Resources, Resource Efficiency

April 2021

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# Executive Summary

The Executive Summary contains a brief synopsis of the solution’s purpose, current status, future adoption expectations, model design, results, and conclusions. The Executive Summary should contain sufficient detail as to serve as a “stand‐alone” summary of the solution. Maximum length one page.

# Literature Review

## State of Recycled Plastics

Plastics production is upwards of 300 million tonnes per year, and over 78 million tonnes of that is plastic packacing (Ellen Macarthur Foundation, 2016). Non-durable plastics, used for short term uses, like packaging, are a major issue because they end up in waste streams, where they can theoretically be collected for reuse or recycling, but typically end up uncollected or in landfill. In fact, 40% of plastic waste is landfilled, and 32% is uncollected and leaks into the environment (Ellen Macarthur Foundation, 2016), which means that the feedstocks to produce recycled plastics are quite limited. Currently, only 2% of plastic packaging undergoes closed loop recycling (where there is no degradation of quality), and only 9% of global plastics are produced from recycled feedstocks at all (Ellen Macarthur Foundation, 2016). Plastics, also, tend to degrade in quality after several cycles, unlike some other materials like metal or glass, though some are more recyclable than others.

Recycled plastics, however, have a significantly lower carbon footprint than virgin plastics, so increasing the amount of plastics recycling through increased collection, reduced yield losses, and incentivization or switching feedstocks from virgin to recycled, could have a significant impact on the global carbon budget of materials. Recycled polymers, also can be cheaper than virgin materials due to energy savings and volatile oil prices.

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## Adoption Path

Collection, sorting and recycling costs are a major barrier to increased recycled plastic production. These costs can be up to 485 euros/tonne in Europe, and $250/tonne in the U.S. These costs are incorporated into the post-consumer pellet or resin costs as well as bottle bundles, making the prices quite volatile.

Increased recovery of post-consumer plastics as well as increased yield are the two limiting factors to feedstock availability. Though recovery has been increasing, the majority of collected plastics still end up landfilled or incinerated (Ellen Macarthur Foundation, 2016). This might be due to challenges with sorting, contamination, etc.

### Current Adoption

Current adoption, as described in 2.4.1, is based on data indicating that the percent of plastic production that was met with post-consumer waste as a feedstock instead of virgin resin was 9% in 2013 and 12% in 2018. Important to note, this is the percent of total production of plastics, or the Reduced Plastic TAM from the Integrated Plastics TAM model. This correlates to 32 MMT of plastic in 2018, which is a much higher percentage of the Recycled Plastics TAM, which serves as an allocation of total plastics that could be produced from post-consumer materials.

### Adoption Potential

Adoption potential is based on sources that identify how much of total plastics (again, the Reduced Plastics TAM from the Integrated Plastics Model) could be produced from post-consumer resin by the year 2050. This varies from between 17% of the total PDS1 Reduced Plastics Tam to 60% of the total PDS3 Reduced Plastics TAM. These values are never to exceed the Recycled Plastic TAM allocation, which serves as a maximum feedstock limitation, to ensure that other replacement solutions (replacement with paper and replacement with bioplastics) also can have their potential met.

## Advantages and disadvantages of Recycled Plastics

### Similar Solutions

Recycled Plastics is one of many necessary approaches for addressing the plastics problem. Reduced consumption of plastic is the first solution, and that with first priority. Of remaining, necessary plastics to meet the remaining demand, 90% of plastics can be replaced by either Recycled Plastics or Bioplastics.   
Bioplastics replaces virgin, fossil-based plastics with bio-based or biodegradable plastics. This technology, however, is less mature, and has undergone smaller market growth than originally projected.

### Arguments for Adoption

Recycled Plastics are a less expensive alternative to Bioplastics in terms of alternative plastics production. The per-unit emissions savings are more consistent, as well, because there is some uncertainty about the implications of land-use change when producing plastics from biomass.

In a system with improved waste management and reduced leakage due to higher rates of collection and processing, as projected in the improved waste system analysis, there will be an increased availability of post-consumer plastics to produce recycled plastics.

## Solution Definition

This solution considers the production of plastic non-durable goods from recycled feedstocks. This replaces the conventional solution of production of non-durable goods from virgin, petroleum based plastics, which are a non-renewable resource. Production from recycled feedstocks avoids waste in landfills, dumps, and leakage into the environment, avoids extraction of oil, and requires less energy for production.

# Methodology

## Introduction

Project Drawdown’s models are developed in Microsoft Excel using standard templates that allow easier integration since integration is critical to the bottom-up approach used. The template used for this solution was the Reduction and Replacement Solutions (RRS) which accounts for reductions in energy consumption and emissions generation for a solution relative to a conventional technology. These technologies are assumed to compete in markets to supply the final functional demand which is exogenous to the model, but may be shared across several solution models. The adoption and markets are therefore defined in terms of functional units, and for investment costing, adoptions are also converted to implementation units. The adoptions of both conventional and solution were projected for each of several scenarios from 2015 to 2060 (from a base year of 2014) and the comparison of these scenarios (for the 2020-2050 segment) is what constituted the results.

## Data Sources

Key sources for analysis of recycled plastics include major investigations of the plastics industry from reports such as:

* The New Plastics Economy, from The Ellen Macarthur Foundation
* Circular Economy, from Materials Economics
* The 2020 State of Plastics, from Plastics Europe
* How plastic waste recycling could transform the chemical industry from Mckinsey
* Scrap Yearbook, from ISRI

That primarily informed major trends in adoption and adoption potential. Also, numerous peer reviewed journal articles were major data sources for emissions and financial data.

## Total Addressable Market / TLA

The TAM data are compiled in the Integrated Plastics TAM model. The complete plastics market is identified, from Plastics Europe (2019), the World Economic Forum (2016), Breaking the Plastic Wave (2020) and Mosko (2012). Breaking the Plastic Wave, Ellen Macarthur Foundation, and Plastics Europe data is used to determine a proportion of total plastics that are non-durable goods, which are within the scope of this analysis.

Plastic reduction scenarios are then determined using Zhen and Suh (2019) analysis, Borelle et al. (2020) ambitious scenario for waste reduction, Greenpeace (2019), Breaking the Plastic Wave (2020) potential reduction, and Becque and Sharp (2020) dematerialization scenarios. The remaining plastic, after reduction, is available for allocation to alternative materials/replacement solutions.

An assumption is made, though, that 10% of plastic demand must be met by virgin plastics, due to technological constraints and specific quality needs.

The remaining 90% of the Reduced Plastic TAM can be replaced either by:

* Alternative materials (e.g. coated plastic)
* Recycled Plastics
* Bioplastics

In that order of priority.

The quantity of plastics that are technologically and economically feasible for recycling and another use in non-durable goods are compiled from Breaking the Plastic Wave (2020), Materials Economics (2020), Becque and Sharp (2020), Plastics Europe (2020), the Plastics Pact and new EU regulations. These average 55% of the Reduced Plastics TAM by 2050. This proportion becomes the Recycled Plastics TAM.

## Adoption Scenarios

Two different types of adoption scenarios were developed: a Reference (REF) Case which was considered the baseline, where not much changes in the world, and a set of Project Drawdown Scenarios (PDS) with varying levels of ambitious adoption of the solution. Published results show the comparison of one PDS to the REF, and therefore focus on the change to the world relative to a baseline.

### Reference Case / Current Adoption

The Reference case is based off of how much of existing plastics are produced from recycled feedstocks. Ellen Macarthur Foundation’s New Plastics Economy indicated that 9% of all plastics production in 2013 were from post-consumer resins, where OECD data indicates in 2018 production from post-consumer resin was 12% of all plastics. These are used with the total Reduced Plastics TAM (not Recycled Plastics TAM) to estimate current adoption, which remains constant for the Ref scenario.

### Project Drawdown Scenarios

Three Project Drawdown scenarios (PDS) were developed for each solution, to compare the impact of an increased adoption of the solution to a reference case scenario, being:

#### Plausible Scenario - This scenario is based on the US growth rate in recycled plastics from 1990 to 2018. The annual increase in plastic recycling was derived from USEPA data, and extrapolated to global values based on consumption of plastic in the US vs. the world as a whole. Annual secondary plastics increase, based on this increase was 0.46 MMt.

#### Drawdown Scenario – This scenario is derived from the Ellen Macarthur Foundation New Plastics Economy report projections that by 2050, 53% of plastics can be feasibly recycled. Combined with a 70-78% yield in the recycling process, the comes out to approximately 37% of TAM by 2050, or an annual increase of 1.7 MMt.

#### Optimum Scenario – The maximum scenario is based on the McKinsey plastics report, which indicates that 60% of production of plastics by 2050 could be post-consumer resin.

## Inputs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable Name** | **Unit** | **Value Used** | **Mean** | **Standard Deviation (SD)** | **Number of Estimates** |
| Current Adoption | MMt Plastic Production | 32.06 | 32.06 | 3.46 | 2 |
| CONVENTIONAL First Cost per Implementation Unit for replaced practices/technologies | US2014$/MMt Plastic Production | 2299509781 | 2299509781 | 2332396833 | 10 |
| SOLUTION First Cost per Implementation Unit | US2014$/MMt Plastic Production | 1478400000 | 1478400000 | 583860685 | 5 |
| Direct Emissions per CONVENTIONAL Functional Unit | t CO2-eq/MMt Plastic Production | 2362804 | 2362804 | 875138 | 41 |
| Direct Emissions per SOLUTION Functional Unit | t CO2-eq/MMt Plastic Production | 663956 | 663956 | 511696 | 15 |
| Recycling Yield | % | 0.00 | 0.74 | 0.06 | 2 |

## Assumptions

Six overarching assumptions have been made for Project Drawdown models to enable the development and integration of individual model solutions. These are that infrastructure required for solution is available and in-place, policies required are already in-place, no carbon price is modeled, all costs accrue at the level of agency modeled, improvements in technology are not modeled, and that first costs may change according to learning. Full details of core assumptions and methodology will be available at [www.drawdown.org](http://www.drawdown.org).

## Integration

The complete Project Drawdown integration documentation (will be available at [www.drawdown.org](http://www.drawdown.org)) details how all solution models in each sector are integrated, and how sectors are integrated to form a complete system. Those general notes are excluded from this document but should be referenced for a complete understanding of the integration process. Integration within the Plastics system is described in the TAM section.

# Results

## Adoption

Below are shown the world adoptions of the solution in some key years of analysis in functional units and percent for the three Project Drawdown scenarios.

Table 3.1 World Adoption of the Solution

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Solution** | **Units** | **Current Year (2018)** | **World Adoption by 2050** | | |
| **Plausible** | **Drawdown** | **Optimum** |
| Recycled Plastics | MMt Plastic Production | 32.06 | 49.01 | 90.87 | 70.73 |
| *(% Market)* | 15.0% | 25.5% | 57.1% | 92.3% |

Figure 3‑1 World Annual Adoption 2020-2050

## Climate Impacts

Below are the emissions results of the analysis for each scenario which include total emissions reduction, atmospheric concentration changes, and sequestration where relevant. For a detailed explanation of each result, please see the glossary (Section 6).

Table 3.2 Climate Impacts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scenario** | **Maximum Annual Emissions Reduction** | **Total Emissions Reduction** | **Emissions Reduction in 2030** | **Emissions Reduction in 2050** |
| *(Gt CO2-eq/yr.)* | *Gt CO2-eq/yr. (2020-2050)* | *(Gt CO2-eq/year)* | *(Gt CO2-eq/year)* |
| ***Plausible*** | 0.03 | 0.49 | 0.01 | 0.03 |
| ***Drawdown*** | 0.10 | 1.66 | 0.04 | 0.10 |
| ***Optimum*** | 0.06 | 1.10 | 0.03 | 0.06 |

The solution was integrated with all other Project Drawdown solutions and may have different emissions results from the models. This is due to adjustments caused by interactions among solutions that limit full adoption (such as by feedstock or demand limits) or that limit the full benefit of some solutions (such as reduced individual solution impact when technologies are combined).

Table 3.3 Impacts on Atmospheric Concentrations of CO2-eq

| **Scenario** | **GHG Concentration Change in 2050** | **GHG Concentration Rate of Change in 2050** |
| --- | --- | --- |
| *PPM CO2-eq (2050)* | *PPM CO2-eq change from 2049-2050* |
| ***Plausible*** | 0.04 | 0.00 |
| ***Drawdown*** | 0.14 | 0.01 |
| ***Optimum*** | 0.09 | 0.00 |

Figure 3.2 World AnnualGreenhouse Gas Emissions Reduction

## Financial Impacts

Below are the financial results of the analysis for each scenario. For a detailed explanation of each result, please see the glossary.

Table 3.4 Financial Impacts

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scenario** | **Cumulative First Cost** | **Marginal First Cost** | **Net Operating Cost Savings** | **Lifetime Operating Cost Savings** | **Lifetime Cashflow Savings NPV (of All Implementation Units)** |
| *2015-2050 Billion USD* | *2015-2050 Billion USD* | *2020-2050 Billion USD* | *2020-2050 Billion USD* | *Billion USD* |
| ***Plausible*** | 94.39 | -47.71 | 0.00 | 0.00 | 47.71 |
| ***Drawdown*** | 291.65 | -157.27 | 0.00 | 0.00 | 157.27 |
| ***Optimum*** | 196.75 | -104.56 | 0.00 | 0.00 | 104.56 |

# Discussion

Results from this solution are lower than that of the Reduced Plastics solution for a few reasons. The first is that recycled plastics still take energy to produce, and therefore do produce CO2 emissions, where reduction in use of a material results in zero emissions. Furthermore, this is the third priority solution in the integrated plastics system, of four. The most aggressive scenario actually has a smaller impact than the PDS2 because of this prioritization. The allocated market share for recycled plastics acts as a feedstock limitation to the more aggressive adoption of recycled plastics because there has already been significant reduction and replacement with other materials.

Despite this, recycled plastics can still produce between 0.5 and 1.6 Gt of GHG emissions savings over the coming decades. The impacts go beyond just emissions reduction, though, as increased recycling means that there will be better end of life collection infrastructure, preventing leakage and the detrimental environmental effects associated with ocean plastics and plastic incineration in informal waste management.

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# Glossary

**Adoption Scenario** – the predicted annual adoption over the period 2015 to 2060, which is usually measured in **Functional Units**. A range of scenarios is programmed in the model, but the user may enter her own. Note that the assumption behind most scenarios is one of growth. If for instance a solution is one of reduced heating energy usage due to better insulation, then the solution adoption is translated into an increase in use of insulation. There are two types of adoption scenarios in use: **Reference (REF)** where global adoption remains mostly constant, and **Project Drawdown Scenarios (PDS)** which illustrate high growth of the solution.

**Approximate PPM Equivalent** – the reduction in atmospheric concentration of CO2 (in **PPM**) that is expected to result if the **PDS Scenario** occurs. This assumes a discrete avoided pulse model based on the Bern Carbon Cycle model.

**Average Abatement Cost** – the ratio of the present value of the solution (**Net** **Operating Savings** minus **Marginal First Costs**) and the **Total Emissions Reduction**. This is a single value for each solution for each **PDS Scenario**, and is used to build the characteristic “*Marginal Abatement Cost*” curves when Average Abatement Cost values for each solution are ordered and graphed.

**Average Annual Use** – the average number of functional units that a single implementation unit typically provides in one year. This is usually a weighted average for all users according to the data available. For instance, total number of passenger-km driven by a hybrid vehicle in a year depends on country and typical number of occupants. We take global weighted averages for this input. This is used to estimate the **Replacement Time**.

**Cumulative First Cost** – the total **First Cost** of solution **Implementation Units** purchased in the **PDS Scenario** in the analysis period. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Direct Emissions** – emissions caused by the operation of the solution, which are typically caused over the lifetime of the solution. They should be entered into the model normalized per functional unit.

**Discount Rate**- the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows. The discount rate in DCF analysis takes into account not just the time value of money, but also the risk or uncertainty of future cash flows; the greater the uncertainty of future cash flows, the higher the discount rate. Most importantly, the greater the discount rate, the more the future savings are devalued (which impacts the financial but not the climate impacts of the solution).

**Emissions** **Factor**– the average normalized emissions resulting from consumption of a unit of electricity across the global grid. Typical units are kg CO2e/kWh.

**First Cost**- the investment cost per **Implementation Unit** which is essentially the full cost of establishing or implementing the solution. This value, measured in 2014$US, is only accurate to the extent that the cost-based analysis is accurate. The financial model assumes that the first cost is made entirely in the first year of establishment and none thereafter (that is, no amortization is included). Thus, both the first cost and operating cost are factored in the financial model for the first year of implementation, all years thereafter simply reflect the operating cost until replacement of the solution at its end of life.

**Functional Unit** – a measurement unit that represents the value, provided to the world, of the function that the solution performs. This depends on the solution. Therefore, LED Lighting provides petalumen-hours of light, Biomass provides tera-watt-hours of electricity and high speed rail provides billions of passenger-km of mobility.

**Grid Emissions** – emissions caused by use of the electricity grid in supplying power to any operation associated with a solution. They should be in the units described below each variable entry cell. Drawdown models assume that the global electric grid, even in a Reference Scenario, is slowly getting cleaner, and that emissions factors fall over time resulting in lower grid emissions for the same electricity demand.

**Implementation Unit** – a measurement unit that represents how the solution practice or technology will be installed/setup and priced. The implementation unit depends on the solution. For instance, implementing electric vehicles (EV) is measured according to the number of actual EV’s in use, and adoption of Onshore Wind power is measured according to the total terawatts (TW) of capacity installed worldwide.

**Indirect Emissions** – emissions caused by the production or delivery or setup or establishment of the solution in a specified area. These are NOT caused by day to day operations or growth over time, but they should be entered into the model normalized on a per functional unit or per implementation unit basis.

**Learning Rate/Learning Curve** - Learning curves (sometimes called experience curves) are used to analyze a well-known and easily observed phenomenon: humans become increasingly efficient with experience. The first time a product is manufactured, or a service provided, costs are high, work is inefficient, quality is marginal, and time is wasted. As experienced is acquired, costs decline, efficiency and quality improve, and waste is reduced. The model has a tool for calculating how costs change due to learning. A 2% learning rate means that the cost of producing a *good* drops by 2% every time total production doubles.

**Lifetime Capacity** – this is the total average functional units that one implementation unit of the solution or conventional technology or practice can provide before replacement is needed. All technologies have an average lifetime usage potential, even considering regular maintenance. This is used to estimate the **Replacement Time**. and has a direct impact on the cost to install/acquire technologies/practices over time. E.g. solar panels generate, on average, a limited amount of electricity (in TWh) per installed capacity (in TW) before a new solar panel must be purchased. Electric vehicles can travel a limited number of passenger kilometers over its lifetime before needing to be replaced.

**Lifetime Operating Savings**–the operating cost in the PDS versus the REF scenarios over the lifetime of the implementation units purchased during the model period regardless of when their useful life ends.

**Lifetime Cashflow NPV**-the present value (PV) of the net cash flows (PDS versus REF) in each year of the model period (2015-2060). The net cash flows include net operating costs and first costs. There are two results in the model: Lifetime Cashflow NPV for a Single **Implementation Unit**, which refers to the installation of one **Implementation Unit**, and Lifetime Cashflow NPV of All Units, which refers to all **Implementation Units** installed in a particular scenario. These calculations are also available using profit inputs instead of operating costs.

**Marginal First Cost** – the difference between the **First Cost** of all units (solution and conventional) installed in the **PDS Scenario** and the **First Cost** of all units installed in the **REF Scenario** during the analysis period. No discounting is performed. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Net Annual Functional Units (NAFU)** – the adoption in the PDS minus the adoption in the REF in each year of analysis. In the model, this represents the additional annual functional demand captured either by the solution in the **PDS Scenario** or the conventional in the **REF Scenario**.

**Net Annual Implementation Units (NAIU)** – the number of **Implementation Units** of the solution that are needed in the PDS to supply the **Net Annual Functional Units (NAFU).** This equals the adoption in the PDS minus the adoption in the REF in each year of analysis divided by the average annual use.

**Net Operating Savings** – The undiscounted difference between the operating cost of all units (solution and conventional) in the **PDS Scenario** minus that of all units in the **REF Scenario**.

**Operating Costs** – the average cost to ensure operation of an activity (conventional or solution) which is measured in 2014$US/**Functional Unit**. This is needed to estimate how much it would cost to achieve the adoption projected when compared to the **REF Case**. Note that this excludes **First Costs** for implementing the solution.

**Payback Period** – the number of years required to pay all the **First Costs** of the solution using **Net Operating Savings**. There are four specific metrics each with one of **Marginal First Costs** or **First Costs** of the solution only combined with either discounted or non-discounted values. All four are in the model. Additionally, the four outputs are calculated using the increased profit estimation instead of **Net Operating Savings**.

**PDS/ Project Drawdown Scenario** – this is the high growth scenario for adoption of the solution

**PPB/ Parts per Billion** – a measure of concentration for atmospheric gases. 10 million PPB = 1%.

**PPM/ Parts per Million** – a measure of concentration for atmospheric gases. 10 thousand PPM = 1%.

**REF/ Reference Scenario** – this is the low growth scenario for adoption of the solution against which all **PDS scenarios** are compared.

**Regrets solution** has a positive impact on overall carbon emissions being therefore considered in some scenarios; however, the social and environmental costs could be harmful and high.

**Replacement Time**- the length of time in years, from installation/acquisition/setup of the solution through usage until a new installation/acquisition/setup is required to replace the earlier one. This is calculated as the ratio of **Lifetime Capacity** and the **Average Annual Use**.

**TAM/ Total Addressable Market** – represents the total potential market of functional demand provided by the technologies and practices under investigation, adjusting for estimated economic and population growth. For this solutions sector, it represents world and regional total addressable markets for electricity generation technologies in which the solutions are considered.

**Total Emissions Reduction** – the sum of grid, fuel, indirect, and other direct emissions reductions over the analysis period. The emissions reduction of each of these is the difference between the emissions that would have resulted in the **REF Scenario** (from both solution and conventional) and the emissions that would result in the **PDS Scenario**. These may also be considered as “emissions avoided” as they may have occurred in the REF Scenario, but not in the PDS Scenario.

**Transition solutions** are considered till better technologies and less impactful are more cost effective and mature.

**TWh/ Terawatt-hour** – A unit of energy equal to 1 billion kilowatt-hours