SUPPORTING INFORMATION

A Review of Global and U.S. Total Available Markets for Carbontech

BUILDING MATERIALS
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- CONCRETES
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WOOD-BASED PANELS

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INTRODUCTION

The current commercial market for carbon dioxide is roughly $8 billion annually, according to the Global CCS Institute. The CO₂ market is almost exclusively sourced from natural sources, and almost all of it is applied to enhanced oil recovery (~70%), with the remainder used in the food and beverage industry.

While entrepreneurial and commercial interest in carbontech products is rapidly growing, there is little research on the total market potential for these products. In this report we make an initial attempt to transparently analyze the potential for carbontech products to be incorporated into existing or potential markets. This report uses open-source data from sources such as British Petroleum, the U.S. Energy Information Administration, the International Energy Agency, and the Alternative Fuels Data Center, and limits reliance on market reports whenever possible to maximize the transparency of calculations.

This report segments markets by product categories, including fuels, chemicals, building material (non-wood), wood and timber, and plastics. In each category, we employed a collectively exhaustive and mutually exclusive framework to ensure markets are not double-counted. For example, we excluded cement from the concrete market assessment to avoid duplicating the valuation of the cement market segment.
WHAT IS THE SCOPE OF THIS REPORT?

This report analyzes the 2017 market volumes (tons, gallons, cubic feet) and values for products that can or could be made with captured CO$_2$ (plastics, fuels, cement, etc.) or other forms of waste carbon, including manure and biomass residues. Carbontech also includes markets for materials that could be made increasingly sustainable through the incorporation of CO$_2$ storage (cements and aggregates). Carbontech can be defined as an emerging industrial sector that captures, transports, and converts different forms of “waste carbon” into a diverse array of valued products and services in a climate-beneficial way. This report provides total available markets for these products within the United States and globally for 2017.

WHAT DOES THIS REPORT DEMONSTRATE?

This report demonstrates that the total available market for carbontech products is currently at the trillion-dollar scale, both domestically and globally. Industries such as fuels and building materials, however, compose the bulk of this market; outside of these commodities, there are several consumer product markets—in the order of billions of dollars—that carbontech is already penetrating.
Building Materials

CEMMENTS

U.S.

The volume of cement consumed in the U.S. was found to be 96.8 million tons and estimated using data from this U.S. Geological Survey (USGS) report. The value of cement produced in the U.S. was found to be $12.4 billion in the same report. To corroborate the market value, we converted tons to metric tons and multiplied the volume of cement produced by the average price of cement in a given year. The average price of cement in 2017 was estimated to be $113 per ton. Thus, (96.8 million tons) * ($113 per ton) = $10.9 billion, which is similar to the $12.4 billion figure from USGS.

Assumption: Most cement sales were to make concrete. In recent years, ready-mixed concrete producers accounted for about 90% of cement sales. As a result, we conservatively estimate the total U.S. market for cement, excluding concrete production, to be $1.24 billion.

GLOBAL

The volume of cement produced globally was found to be 4.1 billion tons and was also estimated using the USGS report; this figure is corroborated by Solidia on its website, which estimates production to be roughly 4 billion tons. The global value of cement was calculated to be about $249 billion. This was estimated by multiplying the volume of cement produced by the average price of a ton of cement. The average price was found to be around $60 per ton, thus (4.1 billion tons) * ($60 per ton) = $249 billion. This is corroborated by Solidia on its website, which estimates the value to be $300 billion. At the global level, we assume 90% of cement production is sold to concrete producers, thus the actual market for cement in the context of this report is $24.9 billion.

CONCRETES

U.S.

To estimate the market sizes of concretes, we made assumptions about the composition of concrete with regard to cement. Using this USGS report, we estimated that around 80% of all cement produced is used for concrete at the global scale; all concrete requires cement, approximately 10% cement by volume. The volume of concrete produced in the U.S. was then estimated to be about 871 million tons. This was calculated by multiplying the volume of cement produced in the U.S. by the portion of cement produced that is used in concrete, and also factoring that only 10% of concrete is made of cement. The equation was (96.8 million tons) * (0.9) * (10) = 871 million tons of concrete. The value of concrete in the U.S. was estimated to be around $65 billion based on this USGS report.

We did not utilize the volumes of concrete to estimate the values because reliable numbers for the average price of concrete in the U.S. and globally were not found.

GLOBAL

The volume of concrete produced globally was estimated to be 33.2 billion tons in the same way using the equation (4.15 billion tons) * (0.8) * (10). This number is corroborated by Solidia on its website, which estimates production to be 33 billion tons. It is also corroborated by the 2009 “Recycling Concrete” report from the World Business Council for Sustainable Development, which estimated global production to be around 27.5 billion tons. The global value of concrete was estimated to be around $1 trillion based on estimates from Solidia. This is supported by the Technavio 2016-2020 Concrete Market Report, which estimates the global concrete market to be roughly $800 billion for 2017, based on its 2020 estimate and working backward with its given 8% compound annual growth rate (CAGR).
Sources citing bitumen and asphalt have been evaluated to ensure they are referring to the same product. The volume of asphalt produced in the U.S. was estimated to be 20.3 million tons. This was estimated using a report by The Freedonia Group Inc., based on its 2021 estimate and projecting backward with its given 3% CAGR. The value of asphalt in the U.S. was found to be around $12.19 billion. This was found by multiplying the volume of asphalt produced in the U.S. by the average price per ton, which is $600 per ton according to this presentation at the MAPA asphalt conference. This calculation is corroborated by The Freedonia Group’s estimate of paving asphalt ($12 billion in 2017). In this estimate, we calculate for paving asphalt exclusively. Cement asphalt is included in the concrete category.

The volume of asphalt produced globally was estimated to be 128.7 million tons, according to this Zion Research report. This is likely a slight underestimate based on a lower price-per-ton value and is corroborated by this IBISWorld report. The value of asphalt globally was estimated to be around $77.2 billion also found by multiplying volume by $600 per ton. The aforementioned Zion Research report corroborates this figure with its estimate that the global value of asphalt would increase from $75 billion in 2014 to $94 billion in 2020.

To estimate the values for aggregates we made assumptions about the definition of aggregates. The USGS includes two categories in its definition of natural aggregates: crushed stone and sand and gravel. We also assumed that more than 95% of the crushed stone and sand and gravel produced is used as construction material. The values found for the two categories are combined to account for the entire aggregate market. According to the USGS Mineral Commodity Surveys for crushed rock and sand and gravel, the volume produced in the United States is around 2.4 billion tons, which was calculated by converting the survey values from metric tons to tons. Separately, The Freedonia Group estimates the volume of aggregates in North America to be around 4.1 billion tons. For this report, we use the conservative estimate from the USGS data. The value of aggregates in the U.S. was estimated to be around $22.7 billion, according to the USGS surveys.

The volume of aggregates globally was estimated to be around 58.6 billion tons, calculated by converting the production figure cited in this Freedonia Group report from metric tons to tons. This number is corroborated by this Aggregates Research article, which estimates global production to be roughly 51.7 billion tons in 2019. The value of aggregates globally was estimated at $466 billion, according to the same Freedonia Group report and using a value of $8.75 per metric ton.
**Wood-Based Panels**

**U.S.**

To estimate the global market for U.S. wood-based panel consumption, we included oriented strand board (OSB), high-density fiberboard (HDF), medium-density fiberboard (MDF), hardboard, and plywood (coniferous and nonconiferous). To calculate the domestic volume of these wood-based panel markets, we used the USDA’s most recent U.S. Forest Products Annual Market Review, which includes all of these products with the exception of hardboard. We excluded both hardboard and soft board from this calculation due to lack of available data on bulk costs and volumes, both domestic and globally. We used the wholesale costs of HDF, MDF, particle board, and plywood found from this retailer, and used the OSB cost listed in this Nordboards financial presentation, which cites Random Lengths Publications Inc. Using these costs and volume we estimated that the wood-based panel market in the United States to be approximately $12.5 billion, which is roughly consistent with a Grandview Market Research study that estimates the market for these products to be $11.6 billion.

<table>
<thead>
<tr>
<th>WOOD-BASED PANEL TYPE</th>
<th>US VOLUME in cubic meters</th>
<th>COST PER CUBIC METER</th>
<th>U.S. MARKET VALUE in millions of dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSB</td>
<td>16,431,000</td>
<td>$293.00</td>
<td>$293.00</td>
</tr>
<tr>
<td>PLYWOOD</td>
<td>11,895,000</td>
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<tr>
<td>HDF</td>
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<tr>
<td>MDF</td>
<td>4,522,000</td>
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<tr>
<td>PARTICLEBOARD</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>38,366,000</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**GLOBAL**

To value the global market for wood-based panels, we used the [Grand View Research study](https://grandviewresearch.com) which estimated the total global market for wood-based panels to be $91.05 billion in 2016; based on the given 6% CAGR, we estimated the 2017 global market to be $96.513 billion. The total volume of wood-based panel consumed globally was found to be 408 million cubic meters, according to the Forest Owners Association, which cites an IndexBox report on wood-based panels as its source.
Chemicals

OLEFINS: ETHYLENE AND PROPYLENE
This document later analyzes the polypropylene and polyethylene markets under the plastics category, but excludes these products to avoid double-counting.

FORMIC ACID
The global market for formic acid in 2016 was $516.9 million. Since it is predicted to grow at a 4.94% CAGR, the 2017 market is estimated to be $542.2 million.

CARBON MONOXIDE
GLOBAL
A Massachusetts Institute of Technology lab has created a membrane system that filters carbon dioxide into a stream of oxygen, leaving behind carbon monoxide. This is the rationale for calculating the market size of only carbon monoxide, as opposed to the secondary forms of CO. Globally, the 2016 market size for CO was $2.8 billion.

SODA ASH \([\text{Na}_2\text{CO}_3]\)

U.S.
To find the domestic consumption of soda ash, we used the USGS Mineral Commodity Report, which indicates that the total volume of soda ash in the US is 11.7 million tons, with a market value of $1.8 billion.

GLOBAL
To find the global market for soda ash, we used a study published by Persistence Market Research, which indicated that the total market was worth $16.375 billion in 2017. We could not find a global volume for all consumption of soda ash.

POTASH/ POTASSIUM CARBONATE \([\text{K}_2\text{CO}_3]\)

U.S.
To estimate the domestic market for potash, we used the USGS Mineral Commodity Report, which estimates 6.1 million tons of consumption (K₂O equivalent) and a global consumption of 42 million tons. The global market for potassium carbonate is around $0.5 billion for 2017, so to find the domestic market, we multiplied the global market for potassium carbonate by the U.S. proportion of the market (14.5%).

GLOBAL
The global market for potassium carbonate is around $0.5 billion for 2017.
Fuels

CONVERSIONS

- barrel of petroleum = 42 gallons
- 1 Mcf of natural gas = 1.037 MMBtu

GASOLINE

U.S.
To find the annual domestic annual consumption of gasoline we used the EIA's annual energy statistics database. To find the total market for gasoline sold in the United States, we multiplied the volume of gasoline consumed by average cost of gasoline for the U.S., as listed in the Global Petrol Prices Database.

GLOBAL
To find the global volume of gasoline consumed we used the EIA's International Energy Data and corroborated with British Petroleum's global volume of gasoline production for light distillate fuels category, which consists of aviation and motor gasolines and light distillate feedstock (LDF). We used the the EIA's 2014 figure, which we conservatively projected to 2017 with a 2% CAGR, for a volume of 388 billion gallons. We converted the daily average consumption figure from barrels per day to gallons per year. To find the total value of the market, we multiplied the total volume by the EIA's global average cost for mid grade gasoline.

JET FUEL

U.S.
To find the annual domestic annual consumption of jet fuel we used the EIA's estimate of annual jet fuel consumed on both domestic and international flights, which was roughly 17 billion gallons in 2017. To find the total market for jet fuel consumed in the United States we used IATA's most recent average cost for jet fuel (October 2018), which was $2.34 per gallon.

GLOBAL
To find the global volume of jet fuel consumed we used the EIA's International Energy Statistics Database, converting barrels per day to gallons per year and projected to 2017 using a conservative 2% CAGR. To find the total value of the market, we multiplied the total volume by the IATA's global average cost for jet fuel, which was an average of $2.35 per gallon.

DISTILLATE/DIESEL FUELS

U.S.
We found the US annual consumption of distillate fuel (No 1. and No 2. in gallons) using the EIA's energy database. To estimate the total market value of diesel fuel in the same database’s most recent average cost for diesel fuel (March 2018), which was $2.63 per gallon.

GLOBAL
Due to lack of available data on global diesel consumption, we used a wider category of distillate fuels, including diesel fuels No. 1, No. 2, and No. 4, and a negligible quantity of heating oils. The total volume of distillate fuel consumption is cited from EIA’s most recent and complete record, and is estimated to be 416 billion gallons per year. To find the total market size for distillate fuels, we use the IEA's data on average global costs for distillate fuels in 2017 ($2.63 per gallon).
NATURAL GAS

U.S.
To find the volume of natural gas consumption in the United States, we employed the [EIA’s Natural Gas database](https://www.eia.gov). To find the total market for natural gas globally, we used the [EIA’s record of Henry Hub spot prices per MMBtu](https://www.eia.gov) and converted to find the cost per Mcf ($2.99/MMBtu=$3.09/Mcf).

GLOBAL
To find the global volume of natural gas consumed we used the [BP Statistical Review of World Energy](https://www.bp.com) and converted cubic meters to cubic feet. To translate MMBtu to Mcf we assumed that 1 MMBtu translates to 1.032 Mcf. To find the total market for natural gas globally, we used the [EIA’s record of Henry Hub spot prices per MMBtu](https://www.eia.gov) and converted to find the cost per Mcf ($2.99/MMBtu=$3.09/Mcf). We then estimated the global average to be roughly double the Henry Hub spot price using [BP’s log of global natural gas market prices](https://www.bp.com) (~$6.18/Mcf).

ETHANOL

U.S.
To find the volume of the annual ethanol market in the United States, we employed the [Department of Energy’s Alternative Fuels Data Center](https://www.afdc.energy.gov), [EIA’s Ethanol Database](https://www.eia.gov), which indicated a global volume of 15.7 billion gallons. To find the total market value for ethanol in the United States, we took the volume in gallons per year, and multiplied by the [US Grain Council’s average cost for ethanol](https://www.grain.org) (~$1.5 per gallon).

GLOBAL
To find the global annual volume of ethanol, we used the [DOE Alternative Fuel Data Center’s estimate](https://www.afdc.energy.gov) for global ethanol consumption. To find the global market value, we multiplied this volume by the [EIA’s average global cost for ethanol in 2017](https://www.eia.gov) (~$1.43 per gallon).

BIODIESEL

U.S.
For the United States’ total volume for biodiesel we used the [EIA’s total volume estimate for 2017](https://www.eia.gov). This estimate includes all U.S. consumption of biodiesel. To estimate the total market value for biodiesel in the United States, this volume was multiplied by the [Department of Energy’s Alternative Fuel Data Center’s most recent average cost for B20 biodiesel in the United States](https://www.afdc.energy.gov) ($3.06 per gallon, July 2018).

GLOBAL
For the global volume of biodiesel we used an [Agricultural Outlook](https://www.fao.org) from the Organization for Economic Cooperation and Development (OECD) and the U.N.’s Food and Agriculture Organization, which estimates the market for biodiesel to be about 33.5 billion liters, which we converted to gallons (8.85 billion gallons). To find the global market for biodiesel, we multiplied the total global consumption by the average global price of biodiesel, taken from the [OECD-FAO Agricultural Outlook 2016-2025](https://www.fao.org) ($2.64 per gallon).

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1 tcf of gas is equal to 28.3 bcm. 1 bcm of natural gas is equal to 35.5 trillion British Thermal Units (or 35,500,000 mmbtu).
**Plastics**

**HIGH-DENSITY POLYETHYLENE (HDPE)**

**U.S.**
To find the volume of HDPE consumed in the United States, we used Plastic Insight’s resin market statistics, which list U.S. consumption in 2017 as 9.4 million tons. To find the domestic market value of HDPE, we multiplied this volume by the average 2017 cost for HDPE ($2,700 per ton).

**GLOBAL**
To find the global consumption of HDPE, we used Plastic Insight’s resin market statistics, which list global consumption in 2017 as 47.5 million tons. We multiplied this figure by the same cost as the domestic price ($2,700 per ton) since the U.S. cost for plastic resin was roughly the average.

**LOW-DENSITY POLYETHYLENE (LDPE)**

**U.S.**
To find the volume of LDPE consumed in the United States, we used Plastic Insight’s resin market statistics, which list U.S. consumption in 2017 as 3.65 million tons. To find the domestic market value of LDPE, we multiplied this volume by the average 2017 cost for LDPE ($2,790 per ton).

**GLOBAL**
To find the global consumption of LDPE, we used Plastic Insight’s resin market statistics, which list global consumption in 2017 as 20.9 million tons. We multiplied this figure by the same cost as the domestic price ($2,790 per ton) since the U.S. cost for plastic resin was roughly the average.

**LINEAR LOW-DENSITY POLYETHYLENE (LLDPE)**

**U.S.**
To find the volume of LLDPE consumed in the United States, we used Plastic Insight’s resin market statistics, which list U.S. consumption in 2017 as 6.94 million tons. To find the domestic market value of LLDPE, we multiplied this volume by the average 2017 cost for LLDPE ($2,950 per ton).

**GLOBAL**
To find the global consumption of LLDPE, we used Plastic Insight’s resin market statistics, which list global consumption in 2017 as 35.1 million tons. We then multiplied this figure by the same cost as the domestic price ($2,950 per ton) since the U.S. cost for plastic resin was roughly the average.

**POLYPROPYLENE**

**U.S.**
For the volume of polypropylene consumed in the United States, we used the Plastic Insights Resin Market statistics, which list U.S. consumption in 2017 as 8.6 million tons. To find the domestic market value of polypropylene, we multiplied this volume by the average cost for polypropylene resin in 2017 ($1660 per ton).
GLOBAL

For the volume of polypropylene consumed globally, we used the Plastic Insights Resin Market statistics, which lists U.S. consumption in 2017 as 73.7 million tons. To find the global market value of polypropylene, we multiplied this volume by the average cost for polypropylene resin in 2017 ($1660 per ton).

Agriculture and Biobased Products

AQUACULTURAL FEEDS
To estimate the global market value for aqua feed (high-density fish protein pellets), we cite a Transparency Market Research Study and adjusted the value with the suggested 11.4% CAGR. This figure is supported by a Research and Markets report that estimates a $98.8 billion market in 2017. There was no open-source data for global or domestic volumes.

ALGAE
To find the current market for algae produced for animal feed, nutraceuticals, and fertilizers, we used an Algae Industry Magazine report, which was based on a Research and Markets study that found the global market for these algae products to be $3.98 billion. A Grandview Market Research study predicted that the global algae oil market is worth $1.5 billion alone, based on the 2015 figure and 4.3% CAGR.

TERRESTRIAL ANIMAL FEED
To find the total market value of terrestrial animal feed markets, we considered feed products that could potentially be replaced with algae feeds. We cite a Markets and Markets research report, which indicates that the global market for these feed products (corn, soymeal, wheat, other oilseeds and grains) is roughly $72 billion.

Consumer Markets

To demonstrate that carbontech has potential markets beyond commodities, we evaluated the total available market for diamonds, vodka, and guitars since there is precedent for each of these consumer goods to be produced from waste carbon feedstocks. Collectively, these markets are worth an estimated $24 billion.

DIAMONDS
Globally, the 2017 diamond market produced 150 million carats, worth an estimated $14.1 billion, according to Petra Diamonds.

GUITARS
We also evaluated the total global market for guitars, given the precedent for guitars to be made from carbontech material. The global annual market for guitars is expected to reach $4.14 billion by 2021, according to research company Technavio.

VODKA
Currently, alcoholic beverages that are high in ethanol can also be produced using captured atmospheric CO2. For this market, we used Reuter’s recent estimate that valued 2017 vodka sales at $6.2 billion domestically.