Sustainability in the Paints and Coatings Industry: Far More than Just a “Good Idea”

By George R. Pitcher, The ChemQuest Group, Inc.

I would like to begin this article with a study in “perspective,” to exercise that man alone, among all living creatures, is capable of undertaking. Working forward from the distant past:

- 240 years ago—The beginning of the Fossil Fuel Age; natural gas first used to light houses and streets
- 180-140 years ago—Coal burned to produce heat for homes; oil followed almost immediately
- 100 years from now—The currently anticipated depletion of proven oil and natural gas reserves
- 150 years from now—The currently anticipated depletion of proven coal reserves
- 180 years from now—End of the “Fossil Fuel Age” (Lasted ~420 years)

Human civilizations have actively occupied the Planet Earth for the past 6,000 years, and for 5,760 of those years, man depended upon wood and peat as sources of material to be burned for both heat and light. Only for the past 240 years have fossil fuels (e.g., coal, crude oil and its various derivatives; natural gas; and bitumen) played a significant role in civilized societies, and—in this short timespan—they have only played major, “front and center” roles in the generation of power for less than a century-and-a-half. Based upon the best currently available estimates, fossil fuels will be depleted within this same timeframe: the coming century-and-a-half. Roughly 400 years out of a total of 6,000 years of civilization. Think about this, and let this staggering fact sink in. …

Fossil fuels have, from the very beginning, been combusted principally as sources of heat, light, and energy, amounting to an 84.3% share of primary energy consumption in the world. NOTE: Non-fossil sources include nuclear (4.3%); hydroelectric (9.6%); and other renewables (5.0%, including geothermal, solar, tidal, wind, wood, and waste). These numbers represent the 93% of fossil fuel consumption which is used for the generation of energy. What about the remaining 7% which accounts for the myriad “other uses” category, containing a vast number of chemicals routinely derived from fossil fuel feedstocks? Fossil fuels can be consumed, but not combusted, when they are used directly as construction materials, chemical feedstocks, lubricants, solvents, waxes, and other products. Common examples include petroleum products used in plastics, natural gas used in fertilizers, and coal tar used in skin treatment products. In 2017, about 13% of total petroleum products consumed were for non-combustible use. Natural gas non-combustion use accounted for about 3% of total natural gas, while non-combustible chemicals derived from coal represented less than 1% of coal use. For all intents and purposes, the organic raw material requirements for the entire paints and coatings industry consist of “non-combusted” fossil fuels, which means that it is a large slice—less than 2% of all fossil fuel consumption. Nonetheless, as fossil fuels become scarcer, they are likely to be shifted from the “other uses” category to sustain energy production, so the need for industries like paint and coatings to convert to sustainable products and processes will be even more intense in the future. This is a sobering thought that receives great lip service throughout the global paint and coatings industry, but disappointingly little substantive action.

Much has been made of “green” chemistry for plastics, fuel, and paints and coatings. This makes eminently good sense, because petroleum-based chemicals will eventually require alternatives—there is only so much oil in the ground, and no more. Replacing fossil fuels and fossil-based chemicals, however, cannot happen overnight, nor should it. For chemical-based industries, the ability to make environmentally sustainable changes in the long term requires sustainable profits and cash flow in the short term. “Green” chemistry development continues, but to what degree does it affect the various segments of the coatings industry? These chemistries from novel, non-petroleum sources are often more expensive than their petroleum-based analogs.

For chemical-based industries, the ability to make environmentally sustainable changes in the long term requires sustainable profits and cash flow in the short term.
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Human civilizations have actively occupied the Planet Earth for the past 6,000 years, and for 5,760 of those years, man depended upon wood and peat as sources of material to be burned for both heat and light. Only for the past 240 years have fossil fuels (e.g., coal, crude oil and its various derivatives; natural gas; and bitumen) played a significant role in civilized societies, and—in this short timespan—they have only played major, “front and center” roles in the generation of power for less than a century-and-a-half. Based upon the best currently available estimates, fossil fuels will be depleted within this same timeframe: the coming century-and-a-half. Roughly 400 years out of a total of 6,000 years of civilization. Think about this, and let this staggering fact sink in. …

Fossil fuels have, from the very beginning, been burned principally as sources of heat, light, and energy, accounting to an 84.3% share of primary energy consumption in the world. NOTE: Non-fossil sources include nuclear (4.3%); hydroelectric (0.4%); and other renewables (5.5%, including geothermal, solar, tidal, wind, wood, and waste). These numbers represent the 93% of fossil fuel consumption which is used for the generation of energy. What about the remaining 7% which accounts for the myriad “other uses” category, containing a vast number of chemicals routinely derived from fossil fuel feedstocks? Fossil fuels can be consumed, but not combusted, when they are used directly as construction materials, chemical feedstocks, lubricants, solvents, waxes, and other products. Common examples include petroleum products used in plastics, natural gas used in fertilizers, and coal tar used in skin treatment products. In 2017, about 13% of total petroleum products consumed were for non-combustion use. Natural gas non-combustion use accounted for about 3% of total natural gas, while non-combustible chemicals derived from coal represented less than 1% of coal use. For all intents and purposes, the organic raw material requirements for the entire paint and coatings industry consist of “non-combusted” fossil fuels, which means that it isn’t a large slice—less than 2% of all fossil fuel consumption. Nonetheless, as fossil fuels become scarcer, they are likely to be shifted from the “other uses” category to sustain energy production, so the need for industries like paint and coatings to convert to sustainable products and processes will be even more intense in the future. This is a sobering thought that requires great lip service throughout the global paint and coatings industry, but disappointingly little substantive action. Much has been made of “green” chemistry for plastics, fuel, and paints and coatings. This makes eminent good sense, because petroleum-based chemicals will eventually require alternatives—there is only so much oil in the ground, and no more. Replacing fossil fuels and fossil-based chemicals, however, cannot happen overnight, nor should it. For chemical-based industries, the ability to make environmentally sustainable changes in the long term requires sustainable profits and cash flow in the short term. “Green” chemistry development continues, but to what degree does it affect the various segments of the coatings industry? These chemicals from novel, non-petroleum sources are often more expensive than their petroleum-based analogs.
The only term that covers both the products that we need to develop for the future, and the types of actions that we need to take to develop those products is: "sustainable." Sustainable raw materials; sustainable finished products; sustainable processes.

With crude oil prices displaying fickle behavior over the past 12 months, going from an historic low of $26.74 a barrel on April 20, 2020 (unleashing a barrage of articles in news services globally, and causing oil stocks to drop down to $46.40 a barrel on March 17, 2021, with a likely average price for 2021 of $60-65 a barrel), can these new chemicals make a sufficiently sizable stride into the various coatings segments and regional markets for them to acquire and maintain a solid, commercially viable foothold? The COVID-19 pandemic set many dominoes tumbling into each other, and each domino that hits the ground has the potential to affect any number of economic forces that may put a damper on significant growth in bioinspired material for paint and coatings, at least for the near-term future. The more important question, however, is: "How do relatively low average prices for crude put a damper on significant growth in bioinspired material for paint and coatings?" In my view, the answer is a qualified "NO." Why "qualified," and why "NO?" To address these two questions, it is necessary to begin defining the long-term issues that are currently, and indirectly, represented by "green," "sustainable," "biobased," "recyclable," and a few other terms. Such terms have hereofore been used by some writers and advocates in limited, even specific, terms; in general, however, they tend to be used interchangeably, which dramatically dilutes both their meaning and their ability to address both change and the actions necessary to effect change.

The only term that covers both the products that we need to develop for the future, and the types of actions that we need to take to develop those products is: "sustainable." Sustainable raw materials; sustainable finished products; sustainable processes. The United Nations defines "sustainability" (in a list of 17 goals), all of which ultimately depend upon each other; some, such as "No Poverty," "Zero Hunger," "Gender Equality," "Reduced Inequalities," and several others, are difficult to tie to the steps that specialty chemical manufacturers and end-users will need to take as we move into the future. A few of those pillars, however, represent aspirational goals that should definitely inform the strategic planning process for specialty chemical industries, in general, and the paints and coatings industry, in particular. They are as follows:


All of these sustainability issues have either direct or indirect relationships with fossil fuels, carbon dioxide and other greenhouse gases, volatile organic compounds (VOCs), bioinspired materials, or any of the other issues that are pertinent to associations with the current products and processes that are dependent upon fossil fuels, and also with the manufacturing processes and processes not based upon fossil fuels that will be required in the future. When the "Fossil Fuel Age" has run its course, the single biggest predictor that all of these "pillars" are interrelated, although some of the connections are certainly more obvious than others. Nonetheless, with the passage of time, the paint and coatings industry is extremely likely to play a direct and critical role in at least eight of the United Nations’ 17 pillars. It is, therefore, time for it to begin changing from the very general usage of multiple terms to describe, in a very vague manner, issues that ultimately have to do with greenhouse gases (as a general rule of thumb: $80-85 a barrel), as well as alcohol and other non-food products that are derived from cellulosic biomass. and developing processes that do not generate carbon dioxide or other greenhouse gases.

I would suggest that the term "sustainable," when used in the paint and coatings industry—and as used in this article—should incorporate at least the following elements, not necessarily in this order, but not necessarily at the same time. These elements of strategy, after all, and plans for implementing strategy takes both time and careful thought:

a. Feedstock: 1. Biomaterials derived from biomass. b. Food: crop-based. Examples would be corn and soybeans, sugar cane and sugar beets. Those should, in general, be avoided, although some use might be acceptable—e.g., sensitive and productive use of seed oils such as soybean, coconut, corn, and rape seed are currently in use, and may need to be for the foreseeable future, at least to some degree.

More interest should be focused on non-food oils, however, such as CNSSL (cashew nutshell liquid), castor bean, Jatropha, karanja (Millletia pinnata), polynia, tamanu (Calophyllum inophyllum), neem, rubber tree seed, mahua oil and others.

The same for both increasing, and decreasing, the rates of production, which are determined from non-food sources, such as corn stover (stems, husks and leaves), cottonwood, buffel grass, straw and others.

b. Non-food use: The leading example is currently biomass from agricultural waste, where there are many other sources/potential sources, such as sawdust, bark and wood chips, garbage, etc.

c. Non-food, non-land use: A good example being currently explored is the use of carbon dioxide as a starting material for making a variety of carbon-based chemicals; this category should also cover waste streams, such as algae and non-food plants from which oils, starches, sugars and biomass could be derived.

2. Less toxic raw materials
a. Increasing use of waterborne paints and coatings, especially if the amount of co-solvent/ VOC content/ VOC plasticizer demand can be reduced to zero or near zero.

b. Continued improvements in crosslinking reactions to eliminate or significantly reduce catalysts, etc.

c. Reduction in use of pigments that contain heavy metals, and pigments that are known or suspected carcinogens, teratogens, and/or mutagens.

d. Replacement of catalysts, emulsi-ifiers, etc., such as organonium compounds, APEO (alkylphenol ethoxylates), P20A (perfluoro-organic acid) and others that have been found to have negative health and/or environmental effects.

e. 100% solids paint and coatings that require no VOC components, in both powder and liquid form.

f. 3. Less energy-intensive processes, such as advances in compact processes in automotive.

4. Products that can be either recycled into different articles of equal or greater value, or down cycled following their effective use periods, and used in coatings that will not interfere with converting the substrates to which they have been applied to their next use.

5. Waste reduction—Products that can be completely recycled; especially polymers that can be easily and economically "upcycled," so that their starting components can be reused in either the same—or different—products.

The is nothing wrong with keeping the terms "green" and "biobased" to the extent that substances used in raw materials sources, which are raw materials derived from fossil-fuel sources—but it should mean something, not just a catch-all phrase used to "greenwash" a product or process. More to the point, "green" alone is only one approach to a paint and coatings industry that is producing sustainable products. There will need to be several synergistically matched approaches to lower energy usage, biodegradability, recyclability, and lower toxicity that will need to be built either into the products or employed to manufacture the products. If one looks at the situation in this manner, it just makes sense to begin thinking about, and planning for, paint and coatings products that are truly "sustainable," rather than merely "green."

CURRENT MACRO ECONOMIC FORCES: OIL DEMAND, PRODUCTION, AND THE STRENGTH OF THE U.S. DOLLAR

Taking a look at global macroeconomics, we project:

- Demand for crude oil in 2020 was 9.2 million barrels per day, a 9% decline from 2019.
- Oil of less importance to the global paint and coatings value chain, there is generally a 2%-5% (as great as 7%) change in raw material costs for every $1/barrel change in the price of Brent Crude.
- U.S. supply of shale oil and alternative fuels such as ethanol has increased.
- In 2018, the United States became the largest global producer of oil and is currently a net exporter of oil. This is likely to remain the situation, at least for the near term.
- Since the price of crude oil is denominated in U.S. dollars, and oil transactions are paid in U.S. dollars, oil pricing weakness as the U.S. dollar strengthens.
- With regard to petroleum chemicals, it is difficult to look with any reason- able certainty beyond 2025 because:
  - Extraction technology is continuously improving, leading to lower production costs.
  - Actions taken by OPEC and/ or measures taken by individual countries, such as Saudi Arabia and Russia, to either decrease or increase production, can have a pronounced effect on the price of crude.
  - Economic growth drives consumption, but many factors (such as COVID-19, recessions, etc.) cannot be accurately anticipated.
  - Cost of renewable energy is declining, but it is not possible to predict for how long the price decline will last, and what point it will stabilize.
The only term that covers both the products that we need to develop for the future, and the types of actions that we need to take to develop those products is: "sustainable." Sustainable raw materials, sustainable finished products, sustainable processes.

goals that should definitely inform the strategic planning process for specialty chemical industries, in general, and the paints and coatings industry, in particular. They are as follows:  
1. Clean Water and Sanitation  
2. Affordable and Clean Energy  
3. Industry Innovation and Infrastructure  
4. Sustainable Cities and Communities  
5. Responsible Consumption and Production  
6. Climate Action  
7. Life Below the Water  
8. Life on Land  

All of these sustainability issues have either direct or indirect relationships with fossil fuels, carbon dioxide and other greenhouse gases, volatile organic compounds (VOCs), biocidal materials, or any of the other issues that are important to associate with the current products and processes that are dependent upon fossil fuels, and also with the replacement products and processes not based upon fossil fuels that will be required in the future. When the "Preindustrial Age" has run its course, less easily justified is the fact that all of these "pillars" are interrelated, although some of the connections are certainly more obvious than others. Nevertheless, with the passage of time, the paint and coatings industry is extremely likely to play a direct and crucial role in at least eight of the United Nations' 17 pillars. It is, therefore, time for it to begin changing from the very general usage of multiple terms to describe, in a very vague manner, issues that ultimately have to do with the replacement of fossil fuels; embracing energy sources that are not derived from fossil fuels; and developing processes that do not generate carbon dioxide or other greenhouse gases.

I would suggest that the term "sustainable," when used in the paint and coatings industry—and as used in this article—should incorporate at least the following elements, not necessarily all, and not necessarily at the same time. These are elements of strategy, after all, and plans and implementing strategy takes both time and careful thought:

a. Materials derived from biosources  
b. Food use/crop-based. Examples would be corn and soybeans, sugar cane and sugar beets. These should, in general, be avoided, although some use may be appropriate—e.g., sensible and productive use of seed oils such as soybean, coconut, corn, and rape seed are currently in use, and may need to be for the foreseeable future, at least to some degree.  
c. More interest should be focused on non-food oils, however, such as CNSL (cashew nutshell liquid), castor bean, Jatropha, karajana (Millettia pinnata), polynaga, tamaru (Calophyllum inophyllum), neem, rubber tree seed, mahua oil and others.  

The same for both increasing, and decreasing, the types of paints and coatings that will not interfere with converting the substrates to which they have been applied into other end uses.  

b. Non-food use. The leading example is currently biomass from agricultural waste, there are many other sources/potential sources, such as sawdust, bark and wood chips, garbage, et al.  
c. Non-food, non-land use. A good example being currently explored is the use of carbon dioxide as a starting material or feedstock, making a variety of carbon-based chemicals; this category should also cover water-based paints, such as aliphatic non-food plants from which oils, starches, sugars and biomasses could be derived.  

2. Less toxic raw materials  
a. Increasing use of waterborne paints and coatings, especially if the amount of co-solvent VOC content of VOC plasticizer demand can be reduced to zero or very low.  
b. Continued improvements in crosslinking reactions to eliminate the use of alcohols, solvents, etc.  
c. Reduction in use of pigments that contain heavy metals, and pigments that are known or suspected carcinogens, teratogens, and/or mutagens.  
d. Replacement of catalysts, emul- sifiers, etc., such as organic amine compounds, APFO (ethylphenol ethoxylates), PFD (perfluoro- orocetic acid) and others that have negative safety and environmental effects.  
e. 100% solids paint and coatings that require no VOC components, in both powder and liquid form.  

3. Less energy-intensive processes, such as advances in compact processes in automotive.  
4. Products that can be either recycled into different articles of equal or greater value, or down cycled following their effective use periods.  
5. Waste reduction—Products that can be completely recycled; especially polymers that can be easily and economically "upcycled" so that their starting components can be reused in the same—or different—forms.

The rest is nothing wrong with keeping the terms "green" and "biocourced" to the full range of subcategories, which is raw materials derived from non-fossil fuel sources—but it should mean something, not just be a catch-all phrase used to "greenwash" a product or process. More to the point, "green" alone is only one approach to a paint and coatings industry that is producing sustainable products. There will need to be several synergistically matched approaches to lower energy use, biodegradability, recyclability, and lower/no toxicity that will need to be built either into the products or employed to manufacture the products. If one looks at the situation in this manner, it just makes sense to begin thinking about, and planning for, paint and coatings products that are truly "sustainable," rather than merely "green."
Sustainability in the Paints and Coatings Industry

Corresponds to global events like the Great Recession of 2008 and, most recently, the COVID-19 pandemic. Wild fluctuations date as far back as the 1940s and 1950s. If we turn our attention to Brent Crude pricing, and looking at the recent history, one can see a similar shift in pricing in the aforementioned timeframe, as shown in Figure 2. Although the precipitous drop that oil has experienced during the first quarter of 2020 is startling, an early-March Brent Crude price forecast places it at approximately $55 per barrel in December 2020, as shown in Figure 3.

When all is said and done, paint and coatings are definitely affected by global and regional economic factors, especially when one or more of those factors, such as the price of crude oil, have a direct effect on raw material costs. Nonetheless, the price and availability of crude oil are only two, albeit very important, factors in determining how the global and regional paint and coatings industry will perform at any given time. What effect the price of oil will have on biobased sources of materials, in general, cannot be known for certain, but it is reasonable to posit that the dynamics driving the use of biobased materials are somewhat different than those driving the use of petrochemical-based analogs, including regulatory fiat, health and safety concerns, environmental issues, energy requirements, consumer preferences, and others. There is, therefore, no reason to believe that the price of crude oil will have any greater effect on interest in, and use of, more sustainable paints and coatings in the post-COVID world than it did in the pre-COVID world.

SUSTAINABLE CHEMISTRY: THE FUTURE?

Biobased materials, are renewable on a routine basis each year, and are, therefore, sometimes referred to as “renewable chemistry,” but really should be folded into the concept of “sustainable chemistry,” because these materials will become an increasingly necessary component of future product analogs of raw materials and finished products that were once produced from fossil fuel components.

There is, therefore, no reason to believe that the price of crude oil will have any greater effect on interest in, and use of, more sustainable paints and coatings in the post-COVID world than it did in the pre-COVID world.

No matter the name, it is chemistry that converts living organisms through a variety of chemical processes, to produce useful chemicals that can serve as finished product components or as reactants to produce a broad range of specialty chemicals, including oligomers and polymers. Table 1 offers an overview of some types of crops and feedstocks used to produce sustainable, biobased raw materials.

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<thead>
<tr>
<th>TABLE 1—Biobased Materials: Origins and High-Level Considerations</th>
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<td><strong>MAJOR FEEDSTOCKS</strong>:</td>
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<td><strong>STARCHES</strong></td>
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<td><strong>BIOLOGICAL</strong></td>
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Source: The Stansford Group Inc.
Sustainability in the Paints and Coatings Industry

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SUSTAINABLE CHEMISTRY: THE FUTURE?

Bio-sourced materials, are renewable on a routine basis each year, and are, therefore, sometimes referred to as "renewable chemistry," but really should be folded into the concept of "sustainable chemistry," because these materials will become an increasingly necessary component of future product analogs of raw materials and finished products that were once produced from fossil fuel components.

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No matter the name, it is chemistry that converts living biomass into a feedstock, to produce useful chemicals that can serve as finished product components or as reactants to produce a broad range of specialty chemicals, including oligomers and polymers. Table 1 offers a summary of some types of crops and feedstocks used to produce sustainable, bio-based raw materials.

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<td><strong>BIO-MASS</strong></td>
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Source: The Strem Chemicals Inc.
Sustainability in the Paints and Coatings Industry

If one considers all uses of biomass chemistry, Table 2 offers some insight into selected chemicals that currently appear to hold the greatest potential for large-scale future use, many of which hold potential for use in the area of paints and coatings. The biobased materials from which they are being produced have made major progress in the development of new applications (Table 2).

PAINTS AND COATINGS: OPPORTUNITIES FOR SUSTAINABLE CHEMISTRY

The breakdown on all components (from any source, petrochemical or biomateri-
als) used in paint and coatings production in the global coatings market in 2020 is illustrated in Figure 4. In 2020 estimates (noted as 2020e), approximately 38.9 MMT of chemi-
cals in the form of pigments, resins, solvents, and additives were used in the global production of paints and coatings. A large category (12.5 MMT) is comprised of pigments, and it is safe to say that inorganic pigments, such as titanium dioxide, fillers, and other inor-
ganic-colored pigments have never been sourced from biomaterials, although it is possible that some may be made from sustainable sources, such as iron, which is indefinitely recyclable. Some organic pigments may be able to use sustainable precursor chemistry, but, as the graph shows, colored organic pigments represent only a small sliver (0.2 MMT) by volume, of total pigment consumption. Producers of these materials, however, constantly strive to reduce the energy needed to manufacture the pigments, minimize the waste, and maximize the yield. In this regard, pigment manufacturers are contributing to the overall sustainability of paints and coatings.

SUSTAINABLE SOLVENTS

Although pigments may not present the most significant opportunity for use in sustainable products, organic solvents used in paints and coatings do. As a portion of all raw materials used in coatings, the solvent category is large, and appears to offer quite a few opportunities for

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**FIGURE 4** — Global Paint and Coatings Industry, by Component (Volume), 2020e, 38.9 MMT

*Does not include 32.9 MMT water*

**TABLE 2** — Selected Biomass Chemicals That Currently Hold Promise for Significant Future Use

<table>
<thead>
<tr>
<th>SUSTAINABLE CHEMICAL</th>
<th>USE</th>
<th>SUSTAINABLE CHEMISTRY PATHWAY</th>
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<tbody>
<tr>
<td>Epoxy resin</td>
<td>Epoxy resins are used as binders in coatings, adhesives, and composite materials.</td>
<td>Epoxy resins are derived from biomass sources like castor oil.</td>
</tr>
<tr>
<td>Polyol</td>
<td>Polyols are used as plasticizers in coatings.</td>
<td>Polyols can be derived from biomass sources like glycerol.</td>
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<tr>
<td>Furfural</td>
<td>Furfural is a platform chemical used in the production of various coatings ingredients.</td>
<td>Furfural is derived from lignocellulosic biomass.</td>
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*Source: The Chemours Company, Inc.*
Sustainability in the Paints and Coatings Industry

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**PAINTS AND COATINGS: OPPORTUNITIES FOR SUSTAINABLE CHEMISTRY**

The breakdown on all components (from any source, petrochemical or biomass-based) used in paint and coatings production in the global coatings market in 2020 is illustrated in Figure 4. In 2020 estimates (noted as 2020e), approximately 38.9 MMT of chemicals in the form of pigments, resins, solvents, and additives were used in the global production of paints and coatings. A large category (12.5 MMT) is comprised of pigments, and it is safe to say that inorganic pigments, such as titanium dioxide, fillers, and other inorganic-colored pigments can never be sourced from biomaterials, although it is possible that some may be made from sustainable sources, such as iron, which is indefinitely recyclable. Some organic pigments may be able to use sustainable precursor chemistry, but, as the graph shows, colored organic pigments represent only a small sliver (0.2 MMT) by volume, of total pigment consumption. Producers of these materials, however, are constantly striving to reduce the energy needed to manufacture the pigments, minimize the waste, and maximize the yield. In this regard, pigment manufacturers are contributing to the overall sustainability of paints and coatings.

**SUSTAINABLE SOLVENTS**

Although pigments may not present as the most significant opportunities for use in sustainable products, organic solvents used in paints and coatings do. As a portion of all raw materials used in coatings, the solvent category is large, and appears to offer quite a few opportunities for biobased, sustainable products. Since the paint and coatings industry represents, on a global basis, the largest usage category for solvents, this is a natural area in which to concentrate research, both for raw material suppliers and paint and coatings formulators (Figure 5). In 2020e, the worldwide market for biobased solvents used in all applications (e.g., inks, coatings, adhesives, household, industrial and institutional cleaners (HICs) and others) is estimated by CHEMRAWN to be $5 billion–$6 billion, and the global solvent market for all solvents is estimated to be $35 billion–$45 billion. While the growth in solvent usage in coatings is only about 2% compound annual growth rate (CAGR), sustainable solvents growth in coatings shows a faster growth rate—approximately 6–7% CAGR—as they make their way back in the market.

**FIGURE 4—Global Paint and Coatings Industry, by Component (Volume), 2020e, 38.9 MMT* (does not include 23.5 MMT water)

<table>
<thead>
<tr>
<th></th>
<th>Solvents, 7.8 MMT</th>
<th>Additives, 1.8 MMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium dioxide, 4.9 MMT</td>
<td>Inorganic colored pigments, 0.5 MMT</td>
<td></td>
</tr>
<tr>
<td>Other pigments, 2.5 MMT</td>
<td>Others, 2.2 MMT</td>
<td></td>
</tr>
</tbody>
</table>

*MMT = million metric tons

Source: The Chevalier Group, Inc.

**FIGURE 5—Solvent Use by Market, by Volume (2019)**

- Other markets 46%
- Paints & Coatings 29%
- Printing 12%
- Oil & Gas 10%
- Cleanin 11%

<table>
<thead>
<tr>
<th>Market</th>
<th>Solvents Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other markets</td>
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</tr>
<tr>
<td>Paints &amp; Coatings</td>
<td>29%</td>
</tr>
<tr>
<td>Printing</td>
<td>12%</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>10%</td>
</tr>
</tbody>
</table>


**TABLE 2—Selected Biosourced Chemicals That Currently Hold Promise for Significant Future Use**

<table>
<thead>
<tr>
<th>Sustainable Chemical</th>
<th>Use</th>
<th>Sustainable Chemistry Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Furfural</strong></td>
<td>Starting component to produce other biomass-based components. Possible terol in subitaneous for lignin-replacement for petroleum-derived materials (oil and gas)</td>
<td>Dethylation of rice, a renewable and cheaper alternative to large quantities of fossil-derived lignin, from wood.</td>
</tr>
<tr>
<td><strong>L-Biotin</strong></td>
<td>Polyethylene and ethylene butene rubbers, used in the production of tires for passenger cars and light-duty vehicles</td>
<td>Convert cyanuric acid to butylated hydroxyanisole and cyanuric acid to butylated hydroxytoluene.</td>
</tr>
<tr>
<td><strong>L-Biotinol</strong></td>
<td>Building block for the production of polymers, solvents, and specialty chemicals</td>
<td>Fermentation of sugars (e.g., glucose) and cellulosic (e.g., corn and wood-derived feedstocks)</td>
</tr>
<tr>
<td><strong>Ethanol</strong></td>
<td>Gasoline blend, solvent</td>
<td>Fermentation of sugars (e.g., glucose) and cellulosic (e.g., corn and wood-derived feedstocks)</td>
</tr>
<tr>
<td><strong>Lactic acid</strong></td>
<td>Food, pharmaceuticals, personal care products, industrial solvents</td>
<td>Fermentation of sugars (e.g., glucose) and cellulosic (e.g., corn and wood-derived feedstocks)</td>
</tr>
<tr>
<td><strong>Sorbitol</strong></td>
<td>Ethanol and lactic acid</td>
<td>Fermentation of ethanol and lactic acid</td>
</tr>
</tbody>
</table>
Sustainable resins can include a variety of products, such as bio-based ethylene and propylene, soybean oil, and vegetable oils. These materials are biodegradable and may not need to be VOCs, depending upon usage and the regulatory environment in which they are being used.

Ethyl lactate is another “green solvent,” as long as it is produced from the fermentation of biomass and not from petroleum. Ethyl lactate is a solvent for use in various paint formulations and is often used in water-based paints.

**SUSTAINABLE RESINS**

Another way for green chemistry to enter the paint and coatings business is through the production of biobased monomers that are used to make important polymers for paints and coatings.

Because alkyds typically contain significant amounts of biobased content from seed oils, they have an automatic head start within the context of “paints, and coatings,” and increased use of alkyds is being encouraged by work in both resin and coatings laboratories.

**Products participating in the voluntary labeling initiative have their biobased content measured using ASTM D6866 as part of the certification process.**

One presumes, without knowing for certain, that the “minimum biobased content” required in products subject to the “BioPreferred” guidelines will be certified by the manufacturers.

Less any vendors should attempt any slight-of-hand subterfuge, however, the biobased content of a coating can be determined using carbon dating. This method measures and compares the ratio of Carbon 14 (C14) to Carbon 12 (C12) in the coating. C14 forms in our atmosphere as cosmic rays interact with nitrogen (N). The percentage of biobased material is simply the ratio of C14 to the total of C14 and C12 divided by total carbon (C12, new carbon plus “old” carbon, from petroleum). Figure 6 describes the source of C14.

Approximately 99% of atmospheric C14 is based on C12; the other 1% of C14 is based on C14. The half-life of C14 is 5,730 years, which means that after 5,730 years, 1/2 of the C14 has decayed to C12; after another 5,730 years, 1/2 of the remaining C14 has decayed to C12; and so on. Each manufacturer and material category specifies the minimum biobased content for products within the category.
Sustainability in the Paints and Coatings Industry

Replacing some petroleum-based, conventional solvents. Growth will certainly continue into the foreseeable future, albeit at a lower rate, given the environmental and regulatory pressure on the use of solvents, regardless of source, and a desire to reduce the dependence on petrochemicals in the major paint-producing global regions—North America, Europe, and Asia-Pacific.

Sustainable solvents can include a variety of products, such as bio-based ethanol from sugar, and methyl styrene from soybean oil. Bioethanol is used largely as a blend with gasoline but can be used in many coatings formulations to replace petrochemical-derived ethanol. Methyl styrene is produced by transesterification of soy fatty acid with methanol. Methyl styrene is the principal component of bio-based fuel and has the potential for use as a solvent in certain types of paints and coatings. Fatty acid methyl esters (FAME), generally referred to as “green solvents” that are analogous to methyl styrene, are biodegradable and may not be considered to be VOCs, depending upon usage and the regulatory environment in which they are being used.

Ethyl lactate is another “green solvent,” as long as it is produced from the cultivation of bacteria and biolactic acid that is gaining traction as a replacement for a variety of commonly used oxygenated and/or petrochemical-derived solvents. Lactate ester solvents can be used in many interior coatings.

Ethyl acetate, butyl acetate, and acetone, though normally sourced from petrochemicals, can be produced through fermentation of sugars from renewable feedstocks. These solvents are selectively used in exterior coatings, varnishes, and inks. Usage is not substantial, however, partly as a result of price and partly as a result of the fact that the cost between “petrochemical-based paints and coatings” and “sustainable paints and coatings” is likely to be governed by “partially sustainable paints and coatings” as progress is made over time.

In addition, the typical use of solvents as part of the issue is to determine the actual percentage of biomass that is used in any given paint and coatings product and, thus, the issue is to determine the actual percentage of biomass that is used in any given paint and coatings product and, thus, to determine the cost of these sustainable materials. Manufacturers of sustainable solvent chemistry, however, continue their research into ways to make these solvents more commercially available and economically viable.

SUSTAINABLE RESINS

Another way for green chemistry to enter the paint and coatings business is through the production of bio-based monomers that are used to make important polymers for paints and coatings. A number of companies have been working on sustainable, bio-based resins for several decades; however, this trend is becoming more mainstream.

Although North America was an early adopter of sustainable solvents (50% share in the world’s resin market in 2014), all global regions are considering and/or already using—green/sustainable resin. Nonetheless, petroleum-based solvents are low-cost, readily available with a well-established infrastructure, and provide a low carbon footprint as a result of process efficiency, all of which offer significant benefits for green/sustainable resins. By 2020, it is estimated that approximately 30% of all new coatings are based on bio-based resins.

Agricultural feedstocks can be used to produce bio-based resins, which are used in coatings and adhesives. These materials can be produced from corn, soybeans, or other agricultural feedstocks. These materials can be used in a variety of applications, including coatings, adhesives, and sealants. These materials are also being used in the production of bio-based plasticizers, which are used in the production of bio-based plastic materials.

Because allyl resins typically contain significant amounts of biobased content from seed oils, they have a structural head start within the context of “paints and coatings,” and increased use of alkyds is being encouraged by work in both resin and coatings laboratories. Products participating in the voluntary labeling initiative have their bio-based content measured using ASTM D6066 as part of the certification process. One presumes, without knowing for certain, that the “minimum bio-based content” required in products subject to the “BioPreferred” guidelines will be certified by the manufacturers. Let any vendors who should attempt any slight-of-hand sleight of hand, however; the bio-based content of a coating can be determined by using carbon dating. This method measures and compares the ratio of Carbon 14 (C14) to Carbon 12 (C12) in the coating. C12 forms in our atmosphere as cosmic rays interact with nitrogen (N2). The percentage of bio-based material is simply the ratio of C12 (C12) to Carbon 12 (C12). The rest of the carbon is divided by total carbon (C6, new carbon plus old carbon, from petroleum). Figure 3 describes the source of C14.

Approximately 99% of atmospheric CO2 is based on C6; the other 1% of CO2 is based on C14. The half-life of C12 is 5,750 years, which means that after 5,750 years, half of the remaining C12 decays to C13; after another 5,750 years, half of the remaining C13 decays to C14. Since nothing other than carbon, nitrogen, sulfur, and oxygen are present in coatings, this is a very useful technique for determining the bio-based content of a coating. The bio-based content of a coating is determined by using carbon dating. This method measures and compares the ratio of Carbon 14 (C14) to Carbon 12 (C12) in the coating. C12 forms in our atmosphere as cosmic rays interact with nitrogen (N2). The percentage of bio-based material is simply the ratio of C12 (C12) to Carbon 12 (C12). The rest of the carbon is divided by total carbon (C6, new carbon plus old carbon, from petroleum). Figure 3 describes the source of C14.

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Having an interest in a new raw material is one thing; using a material in commercial applications is quite another thing. Respondents in the SCO survey, however, offered insights into headwinds facing biobased raw materials, shown in Figure 8. It should come as no surprise that the cost/performance concern was the greatest. All other concerns carried more or less the same weight and were grouped together as “All Other Concerns.”

**BEYOND THE “BIO BUZZ”**

The results of the European Coatings Journal survey article support Anderson’s axiom, first promulgated in 2010 by Susan St. Anderson, prominent coatings and adhesives industry observer and specialty chemicals management consultant, and director, The ChemQuest Group, Inc., to wit: Perhaps 5-8% of individual consumers will pay a 40% premium for “green” paint. (“Sustainability” is not yet a concept fixed in the average consumer’s vocabulary.) In the world of industrial coatings, however, you are unlikely to be able to command a premium for products that are “green,” “sustainable,” “bio-based,” or better for the environment, made with less energy, or produced with a lower carbon footprint. You are, however, more likely to achieve a “more favored status” by selling such products at a realistic price and competing against successful products. There is greater interest in cost/performance considerations for bio-based raw materials and articles than in sustainable products and articles. There is greater interest in bio-based materials, but it needs to be expanded into an interest in “sustainable products and processes,” because that is what the future will require as we approach the end of the fossil fuel era.

There is greater interest in bio-based materials, but it needs to be expanded into an interest in “sustainable products and processes,” because that is what the future will require as we approach the end of the fossil fuel era. Currently, things really come down to a common hurdle that all new raw material producers face in the paints and coatings arena—and that paint and coatings producers face, in turn, in their end-use customers: cost/performance ratio. If a raw material is more expensive, it must provide one or more positive attributes that justify the higher price. One of those attributes might very well be “sustainability,” which will satisfy a variety of national and local regulatory mandates and be of compelling interest to a certain percentage of both businesses and consumers for whom “sustainability” adds value to a product and justifies its value-added pricing. For the majority of users of paints and coatings, however, the tipping point where “value-added” pricing of sustainable products meets the “cost/performance” requirements of the industry is going to occur. When that happens, they will meet all criteria implied by the term “sustainable.”

Currently, the percentage of businesses and consumers with a serious interest in manufacturing and marketing sustainable products and articles is quite low, but over time it must increase, and it will increase, as long as every participant in the value chain does its part to engineer more sustainable raw materials. There is more interest in sustainable products, for use in more sustainable end uses, all of which can be recycled at some point, so that we can arrive at a truly global circular economy. It’s not a question of “if,” but rather of “when.” We could easily be looking 20 or more years down the road for this to happen, but 20 years will go by in the twinkling of an eye, so the time to start replacing fossil fuel components with sustainable, biosourced, and other renewable/recyclable components is NOW.

**References**


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