Fragrances and Sustainability

Assessing the impacts of changing consumer consumption habits, green chemistry, biotechnology and sourcing strategies.

Torsten Kulke, Symrise

Fragrance is a vital part of consumer product acceptance and preference, or, even a sensory messenger of performance. Most bulk formulation ingredients can be assessed for their environmental and societal impact. However, this is more difficult for fragrances, which are complex mixtures of many aroma chemicals or essential oils.

The fragrance industry uses more than 4,000 ingredients, of which more than 60% are used by the entire industry below 1 ton/annum. This relative complexity and the indefinite combinations that can be derived thereof make fragrances exciting, but also tremendously complex (**F-1**). In recent years, the topic of sustainability has embraced the fragrance industry and is currently actively discussed.[1–3,a]

The central questions this paper examines are: 1) what relative role is the fragrance industry playing in the global sustainability debate; 2) what impact does fragrance have in the consumer product lifecycle; and 3) what opportunities does the fragrance industry have to contribute to sustainability?

The Sustainability Role of the Fragrance Industry

Despite the "great recession" and slowing growth dynamics in many emerging markets, consumers are globally increasingly concerned about the human ecological footprint's impact on biodiversity, global warming and resource availability. The World Business Council for Sustainable Development projects that, by 2050, humans will consume 2.3 earth equivalents if they continue with "business as usual."[4] At present, humans consume approximately 1.4 earth equivalents, thus the imperative to act is crystal-clear (**F-2**).

Within this context of an "over-consumed" world, how does the fragrance industry fit in? Due to the complexity of the fragrance raw materials used globally, there is little hard data available, and many insights require extrapolation from industry expert opinions.

The industry's focus lies chiefly on fragrance raw materials and not the solvents that are often used to meet specific customer requirements. Symrise estimates that global annual fragrance consumption is about 500 thousand metric tons. Further, based on extrapolating Symrise's own consumption and input from industry experts, it is assumed that approximately 5% of global fragrance volume stems from nature (such as essential oils, extracts, concretes), while about 80% is based on fossil sources and 15% on renewable resources, mainly crude sulfur turpentine (CST) and pine oil (**F-3**).

For comparison, global PET (polyethylene terephthalate) consumption, commonly used for water and soft-drink bottles, stood at 49.2 million tons in 2009.[5] Global detergent use is estimated to be about 15.0 million metric tons.[6] Clearly, if one refers to the above two examples, the global fragrance industry plays an insignificant role from a volume perspective, let alone if one considers the global chemical industry output or total global manufacturing.

At a Glance

Fragrances play a key role in consumer products and are multi-component mixtures of various origins. Sustainability and fragrances is a hot topic, despite the relatively low dosage of fragrances in comparison to other formulation ingredients.

A plurality of approaches is currently being discussed, such as renewability, sustainable sourcing, green chemistry and biotechnology. The most surprising finding is that using fragrances to support changes in consumer product consumption habits is the biggest sustainability opportunity. For instance, fragrances that give consumer confidence in lowering laundry wash temperatures or reducing shower durations are the major opportunities.

In the fragrance industry, green chemistry offers the biggest sustainability lever, next to changes in consumer consumption habits. By volume, approximately 95% of the fragrance ingredients are chemically processed, which explains the importance of green chemistry, next to more concentrated, "high-impact" innovation.

Simultaneously, the fragrance industry should complement chemistry approaches with sourcing partnerships, particularly for valuable natural products, to improve livelihood resilience and origin traceability.

New and emerging technologies, such as biotechnology, can complement the above approaches, but are unlikely to deliver short-term step-change benefits.

[a]"Smart Sustainability" and "Ingredients for a Sustainable Future" panel discussions at the World Perfumery Congress 2014, June 11 and 12, respectively, in Deauville, France.

In conclusion, the fragrance industry plays a small, almost insignificant role from a global sustainability perspective. However, given the urgency of advancing the sustainability agenda, every industry is required to provide tangible solutions to mitigate its footprint, regardless of industry size and current impact.

The Fragrance Factor in the Laundry & Personal Care Product Lifecycle

Until recently, there has been limited hard data on consumer product lifecycles. In 2014, Martinez et al. published a comprehensive lifecycle analysis on liquid laundry detergents.[7] Their main conclusion is that the biggest driver for energy use is the heating of water for the laundry cycle. Reducing the wash temperature from 40°C to 20°C more than halves the global warming potential. If consumers switch to so-called cold washes of 20°C, raw materials account for 30% of the global warming potential of a laundry load (**F-4**).

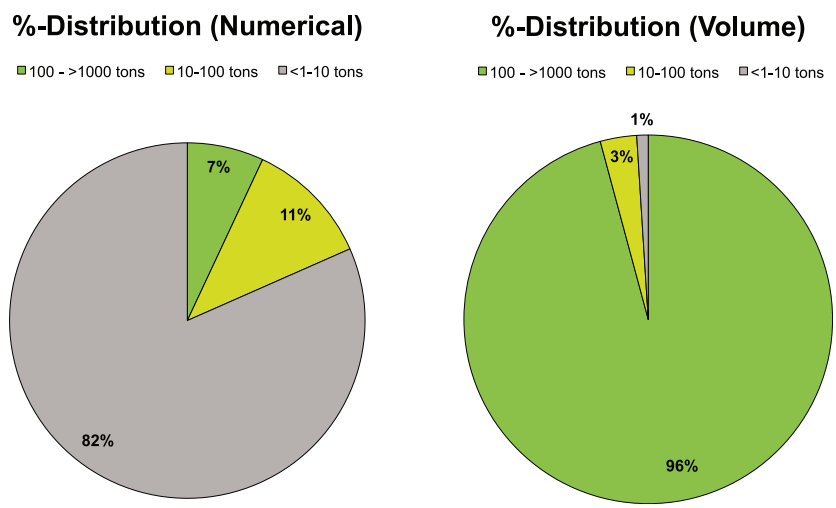
Given that fragrances are typically dosed at significantly less than 1% in laundry detergents, the total impact of the fragrance on the overall consumer product lifecycle will be much less than 1% at 20°C. This figure will get proportionally lower if consumers continue with their habits of higher wash temperatures in frontloading machines. Thus, the biggest sustainability contribution a fragrance can offer is to help consumers engage in more sustainable consumption habits.

Martinez et al. state the average temperature of laundry wash cycles in Germany is 46°C. If the fragrance can support "cleaning cues" for clothes washed at lower temperatures, many consumers may be enticed to switch. For instance, Finke reports that the fragrance industry can offer technologies to overcome "wet fabric" malodor caused by low-temperature washes and even provide positive freshness cues through encapsulation technologies now available for liquid detergents.[8] Encouraging a consumer habit change would lead to significant changes in the carbon footprint of every laundry cycle.

A similar case can be made for personal care products. The following example illustrates the opportunity, even if the figures are based on estimates and extrapolation. These assumptions in no way invalidate the findings; they merely point out that further in-depth research is required for higher accuracy.

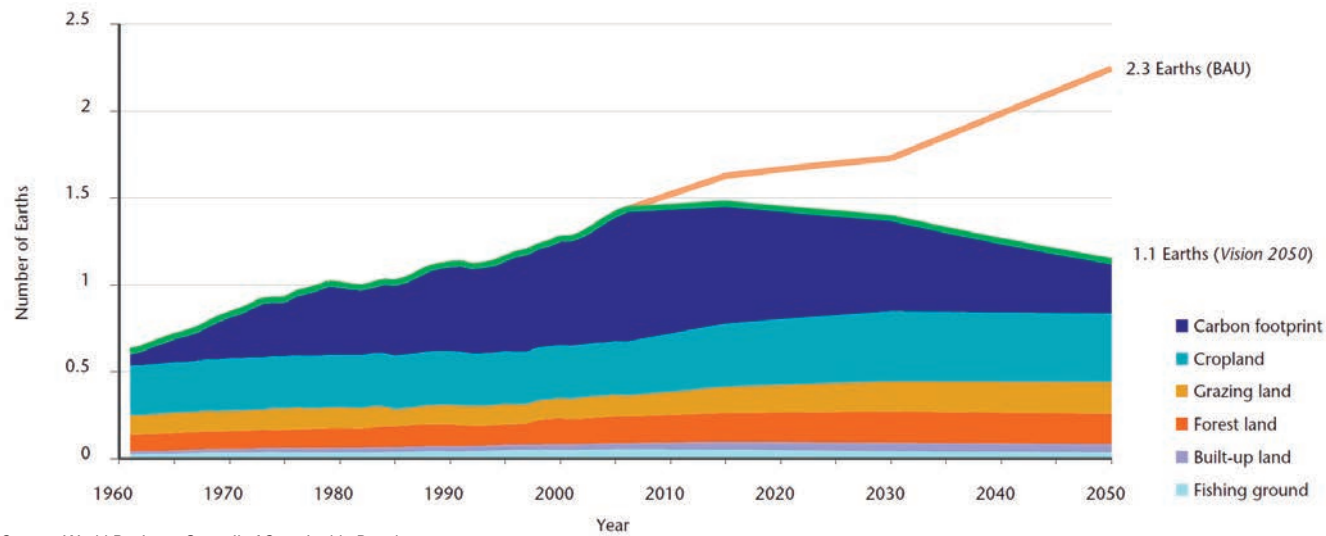
Looking at the shower routine that most consumers covet,

F-1. Percent-numerical distribution of volume bands (left) and absolute volume use of respective volume bands (right)*



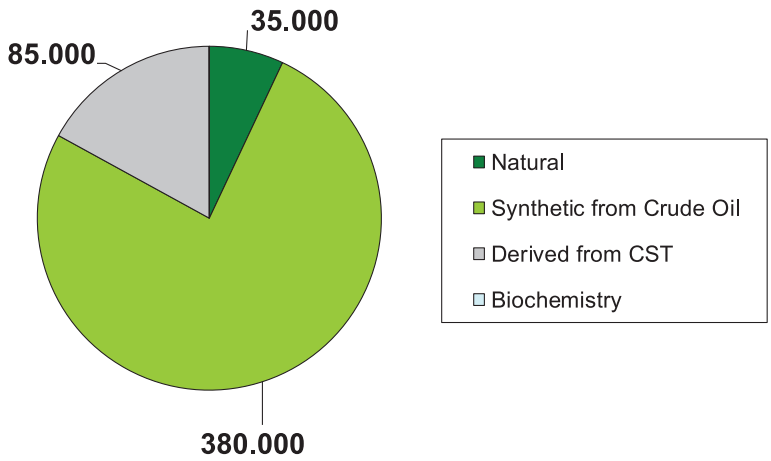
*Sources: Left: International Fragrance Association (IFRA) 2008 and 2011 volume-use surveys. Right: Symrise estimate based on IFRA volume-use surveys and assuming the following average annual volume consumption per raw material per volume band: >100 t/a average consumption 2,500 t/a; 10–100 t/a average consumption 50 t/a, 1–10 t/a average consumption 5 t/a. In essence, it is vital that the industry focuses primarily on the big-volume materials.

F-2. The global footprint of humanity*



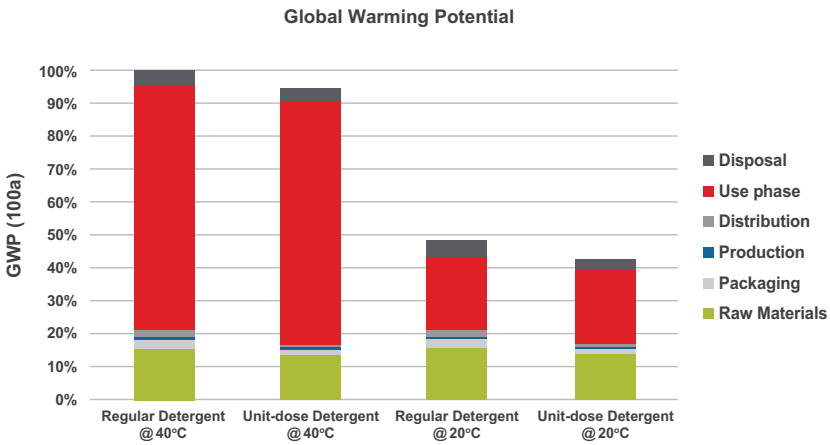
*Source: World Business Council of Sustainable Development.

F-3. Estimated feedstocks of global fragrance*



*Solvents are excluded; volume assumptions are approximate and based on expert opinion.

F-4. Drivers of global warming potential for liquid detergents[8]*



*Source: Martinez et al.

not only for hygiene but also indulgence and relaxation, water again emerges as the biggest footprint driver. For each shower, the fragrance-related global warming contribution is calculated to be about 1 gram CO_2 equivalent.[b] For instance, in Canada the footprint of an average shower is about 2.2 kg CO_2 equivalents, based on the following public-domain data: 7.6 minutes shower length, 15 liters of warm water/minute and 19 grams CO_2 equivalents/liter of shower water.[9,c]

Even though each consumer has different showering habits, it is evident that a shorter shower will have tremendous bearing on global impact, whilst the fragrance impact will be almost negligible. However, if the fragrance industry, together with consumer goods companies, could design products that encourage consumers to reduce shower times or frequency of showers altogether, this would lead to a significant carbon (and, also increasingly important, water) saving at the global scale—arguably a simultaneous challenge and opportunity.

Based on these examples, it is evident that fragrances play an insignificant role in direct impact terms within the typical consumer product lifecycle. Consumer habit changes will lead to noticeable footprint reductions. Symrise has embarked on a sustainable formulations project to inspire and support customers in their challenge to break consumer routines, and thereby reduce water and carbon footprints.

Fragrance Ingredient Lifecycle Assessment

Due to the overwhelming complexity of materials the fragrance industry uses, there is limited hard data available for most fragrance ingredients. A recent publication of the Research Institute for Fragrance Materials (RIFM) focused on a lifecycle assessment of five selected fragrance raw materials, two which are petrochemically derived, two of which are based on renewable feedstocks and one of which is a natural essential oil, namely patchouli.[d] The report investigated various dimensions such as resource use and downstream impact. The key findings are that resource use appears more pertinent than downstream use, since fragrance use is widely dispersive, resulting in low environmental concentrations overall.

Extracting from the report the data for water use and global warming CO_2 equivalents per kg of fragrance material, it may appear surprising that naturally sourced patchouli oil has a high carbon and water footprint. Patchouli's footprint is one and three orders of magnitude higher than comparable fragrance materials obtained from renewable or petrochemical resources, respectively. The reasons for the disproportionally high water use for patchouli oils lie in crop irrigation, washing, cleaning and steam distillation (**F-5**).

Energy use is driven by the use of fuels for steam distillation. Heating water requires a lot of energy, but converting water into steam is even more energy-intensive because of water's high energy of vaporization. Given that many essential oils are produced at small farms, often in less developed parts of the world, data on energy- and water-efficient production methods are elusive.

These figures of high resource use are congruent with Symrise's own research on the carbon footprint for synthetic versus natural menthol. Symrise estimates that natural menthol produces 50–100 kg/CO_2 equivalents versus 8 kg for synthetic

[b]This value assumes the following scenario: the consumer uses 10 grams of shower product in total, with an average fragrance dosage of 1% and a fragrance footprint of 10 kg CO_2 equivalents/kg of fragrance.

[c]The conclusion of the high-energy footprint for heating water and low-fragrance footprint will remain, even if changes are applied to the energy source used for heating the water, cold water supply temperature, hot water temperature at the faucet, shower duration, water flow and product quantities used (e.g. shower gel, soaps, shampoos and conditioners).

[d]RIFM's "Lifecycle Assessment of Selected Fragrance Materials," *www.rifm.org* (2013)

menthol. This is not to say that naturals are major contributors to global warming, but clearly artisanal-type production of essential oils cannot compete with the efficiency of modern chemistry. This statement will be generally valid for steam-distilled essential oils, but will be very different for cold-pressed citrus essential oils such as orange, lemon or bergamot. Data on these oils is not published, but it is assumed that impacts are not higher than for chemically converted raw materials.

Attempting to calculate the global impact for the five raw materials covered in the RIFM report, 45,000 metric tons of fragrance ingredients produce approximately 470,000 metric tons of CO_2 and use about 81 million metric tons of water. Patchouli accounts for 3% of the volume, but 40% of CO_2 emissions and 98% of water use. On the other hand, dihdyromyrcenol represents approximately 50% of the volume and 35% of CO_2 emissions.

Based on F-5, it is fair to assume that average fragrances will have a global warming impact of 10 kg CO_2/kg fragrance, unless they are very rich in essential oils derived from steam distillation. This value is not out of line with other specialty chemicals used in the detergent industry and Symrise's own estimates.[7]

As observed previously, it is clear that changing consumer habits is the biggest potential lever to reduce footprint at a product level. At a fragrance level, natural essential oils obtained via steam distillation will generally have significantly higher footprints than chemically produced ingredients, even if the former will have a minor contribution at a global scale.

Fragrance Industry Sustainability Contributions

The fragrance industry evolved historically from nature, and it was not until 1855 that the first synthetic materials like benzaldehyde or phenylacetic acid entered the fragrance industry palette. In 1874, Wilhelm Haarmann discovered that the renewable feedstock coniferyl alcohol, a side product from fir trees, could be chemically converted into vanillin. Over the past 140 years, the number of fragrance ingredients that were produced using chemical conversion has grown significantly and represent, currently, about 95% of volume (F-3).

The Focus on Naturals

However, the current discussions in the public domain on fragrance sustainability topics are almost exclusively in the fields of sustainable sourcing and biotechnology.[1,10,11] There are three main drivers behind this orientation.

The first is securing supply in view of crop competition and urbanization. Nowadays, it can be lucrative for farmers to focus on alternative cash or energy crops that may deliver a higher economic benefit than producing essential oils. Labor-intensive farming is on the decline, as many farmers either abandon the country for city life or focus on more easily producible crops.

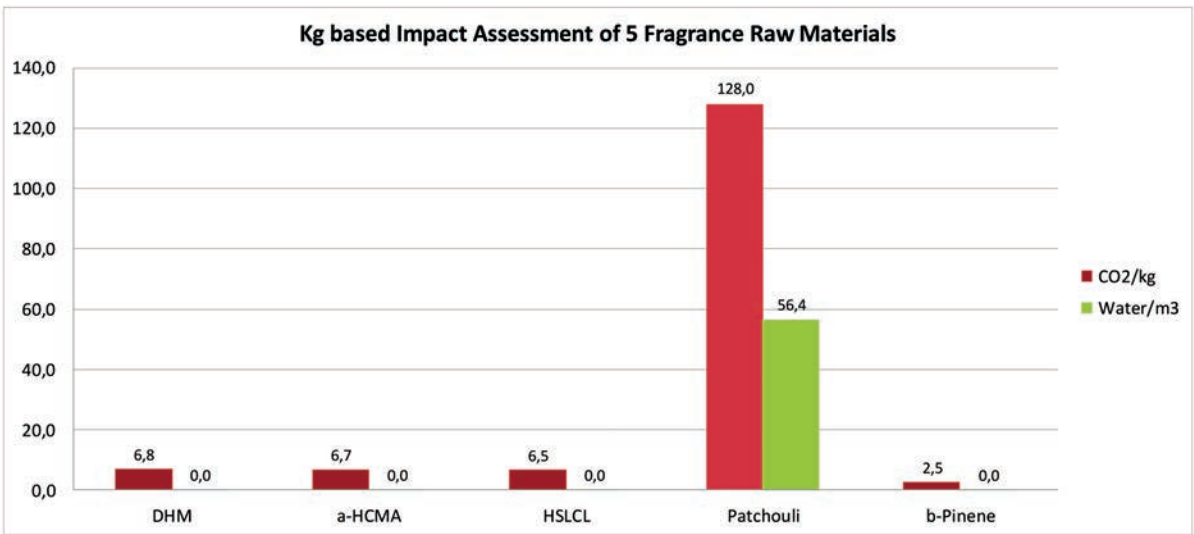
Second, cottage farming, as is commonly the case for essential oils, often brings about inefficiencies in growing and extraction, leading to a high ecological footprint for the economic value added. On the other hand, fostering income, education and production efficiencies improves livelihood resilience of these rural communities, which in themselves often have far more sustainable living patterns than those in industrial or urban settings. Here lies the biggest opportunity in sustainable natural production, sharing the socioeconomic value and encouraging communities to maintain overall more sustainable living habits versus their industrial peers.

Third, the fragrance industry is about emotions; thus, natural feedstocks, selected qualities and defined origins play a big role in communication strategies for consumers, customers and NGOs alike. And, yes, happy farmers in remote locations create more connective imagery than chemical mono-plants, despite the fact that 95% of fragrance materials touch chemistry.

Biotechnology's Contribution to Sustainability

Industrial biotechnology is a new technology upon which some companies from a fragrance industry perspective have invested

F-5. Carbon and water footprint of five fragrance raw materials at estimated global consumption values*



*Data sources: global consumption in thousand metric tons/annum—Symrise; carbon and water footprints in thousand metric tons and million metric tons, respectively—RIFM; DHM = dihydromyrcenol, α-HCMA = α-hexylcinnamaldehyde, HSLCL = hexylsalicylate

significantly. While biotechnology has been used for many years for low-volume high-cost specialties, it was not until 2014 that Firmenich introduced its trademarked Clearwood, which is produced from sugar and intended to be a patchouli oil replacement.[12]

It remains to be seen if these biotechnology essential oils will be cheaper, lower in ecological footprint and higher in societal value than their conventionally produced materials. Currently, biotechnology largely aims to replace some of the 5% of higher-value naturals that are consumed by the fragrance industry. Thus, its sustainability impact is at least in the short-term limited.

There are some caveats that merit consideration. Removing high-value essential oils from nature may risk depriving rural communities of much-needed income and sustainable living patterns. Furthermore, biotechnology watch-outs are the use of food feedstocks and engineered enzymes. Nevertheless, biotechnology will likely play a larger role in the future.

The Significant Impact of Green Chemistry

In view of the fact that the vast majority of fragrance ingredients now, and in the foreseeable future, will undergo a chemical conversion process, it is here that the fragrance industry has the biggest leverage to reduce its footprint. However, the potential for efficiency improvement in the fragrance industry is largely undiscussed in the public domain.

Paul Anastas coined the term "green chemistry" in 1998 to drive 12 measures of eco-efficiency into chemical processes and molecular design strategies. As articulated by R. Sheldon in his lecture at the Symrise 2014 Niclas Symposium, "Green chemistry efficiently utilizes (preferably renewable) raw materials, eliminates waste, and avoids the use of toxic and/or hazardous solvents and reagents in the manufacture and application of chemical products."[13]

As stated by Sheldon, green chemistry is about minimizing impact through design and processes, avoiding waste and hazards, and focusing on efficient raw material use and renewability, where possible. Thus, green chemistry is clean chemistry. In 2001, Panten published a first review of green chemistry in the fragrance industry in the now historic "Dragoco report."[14]

Along with Symrise, Renessenz has also focused on green chemistry communication. Kolomeyer reported that the redesign of the carvone process reduced waste nine-fold, while at the same time nearly halving carbon impacts.[15] Similarly, Symrise is producing menthol with minimal waste and high carbon efficiency, with one fifth, or less, of the impact of naturally produced menthol (**F-6**).

There are two challenges to green chemistry, the first of which is "process greenwashing," in which companies over-claim marginal improvements. Kolomeyer calls this "infinite shades of green," and maybe there is a case for a "green chemistry quality charter" to prevent fraudulent misuse.

The second challenge is the difficulty of measurement at the process level in order to obtain hard data. Most fragrance ingredients are batch-produced in multipurpose production equipment, rendering accurate cradle-to-grave assessments more difficult. A short-term recommendation is to focus on larger-scale continuous processes before embarking on

smaller-scale batch processes. Finally, focusing on the volume ingredients will deliver the biggest gains (F-1).

A third important aspect is environmental fate, ecotoxicology and water footprint. Historically, this has been less of a focus, but recent registration and sustainability demands, as well as public concerns, have elevated this vital green chemistry principle.[16]

The Benefits of Concentration

Next to green chemistry, more concentrated fragrance ingredients ought to play a vital role in the fragrance and consumer goods industry. To use the terms of F-2, the challenge is to bring consumption back to below one earth equivalent. If each industry works on reducing its total footprint by 50% over the next two decades or so, society should be on a sustainable trajectory. For the fragrance industry, this would mean achieving more olfactory impact from less fragrance volume. If the fragrance industry currently produces half a million metric tons of scent to meet the global consumer needs, in 20 years it should require no more than a quarter of a million metric tons. However far-fetched this concept may appear, this ought to be our cross-industry challenge.

Currently, there are numerous high-impact fragrance materials available that are at least one order of magnitude more efficient than many traditional fragrance ingredients. However, cost—but also lack of creative learning and usage challenges—have so far limited success and uptake of these compounds. That said, the fragrance industry is lucky to already have materials with the potential to decouple economic growth from material consumption.[e] Clearly, this is also a research and innovation imperative for the industry going forward, next to green chemistry, biotechnology and responsible, equitable sourcing.

[e]Imagine asking a car company to reduce carbon footprint by 10-fold, let alone 100-fold.

Chemistry is the lifeblood of the fragrance industry, thus green chemistry and more concentrated fragrance solutions offer the biggest sustainability lever. Meanwhile, naturals play an evocative role, where sustainable, value-sharing sourcing strategies offer a complementary industry sustainability opportunity.

Sustainability Summary and Conclusions

In the global context, the fragrance industry is comparatively small, with an estimated annual consumption of 500,000 metric tons of fragrance materials, representing about 0.0033% of global crude oil output for its manufacture. During the use of fragranced consumer products, the direct fragrance impact on the overall product lifecycle is negligible. Other raw materials and, most pertinently, consumer habits are the real drivers of impact.

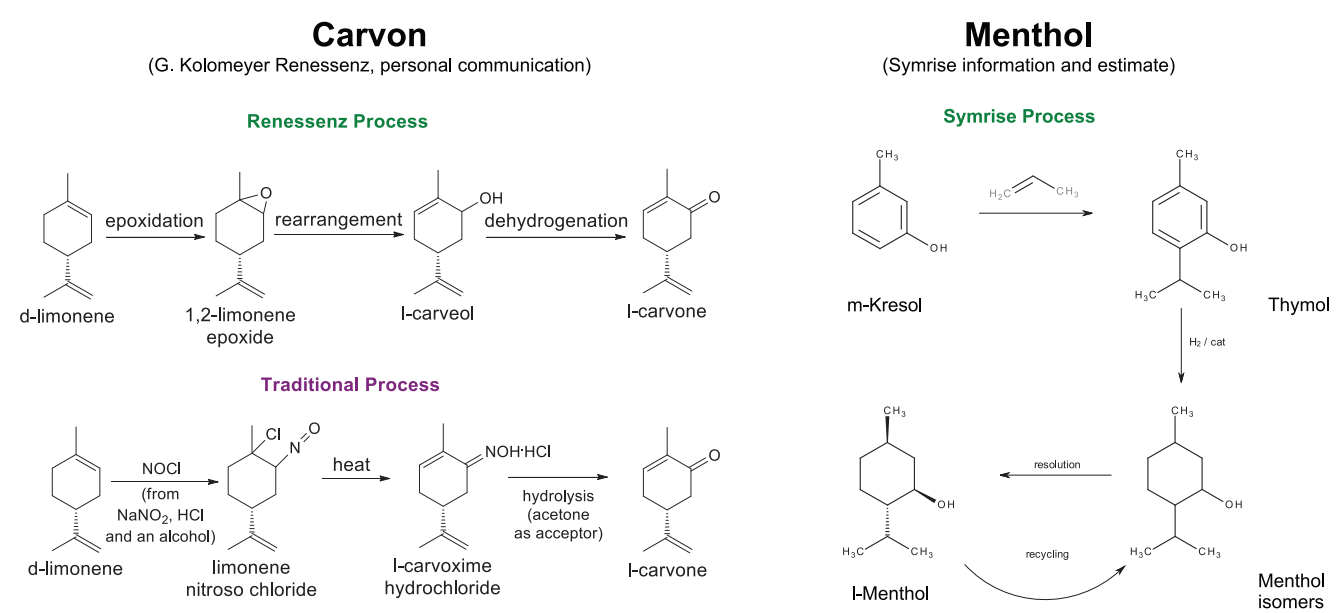
First and foremost, the biggest and most impactful sustainability contribution the fragrance industry can make is to help support changes in consumer habits, such as turning to lower laundry wash temperatures or reducing shower frequency and/or duration. Positive sensory cues of cleanliness and hygiene, or the effective fragrancing of alternative product offerings, could substantially reduce resource use and carbon impact.

Next to facilitating changes in consumer habits, which is arguably rather challenging, the fragrance industry should focus on sourcing natural ingredients and essential oils in the most ecological and societally responsible way so as to promote sustainable living practices of communities and smallholder faming.

Third, and at least as important, the fragrance industry should relentlessly make chemistry smarter via green chemistry and reducing resource consumption via high-impact materials. In order to accelerate the sustainability agenda even further, a focus should be maintained on high-volume ingredients that are used at e.g. at 1,000 tons/annum or more.

Last, but not least, a common fragrance sustainability charter should be developed by forging an industry alliance

F-6. Examples of green chemistry processes: menthol (Symrise) and carvone (Renessenz)*[15]



*Both ingredients are produced at the 1,000 ton/annum levels, delivering significant environmental benefits.

of producers, fragrance companies and consumer goods companies, potentially through the fragrance industry's research arm, RIFM. Currently, each company is aiming to develop its own strategies, as witnessed in numerous sustainability reports. Whilst all the efforts and strategies are laudable at the individual company level, the fragrance industry would benefit from a unified "sustainability roadmap." Leading the way is the cleaning industry. A cross-industry "sustainable cleaning charter" (*www.sustainable-cleaning.com*), driven by AISE, the International Association for Soaps, Detergents and Maintenance Products, has delivered an estimated carbon footprint reduction of 24% over a seven-year time period.

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Address correspondence to Torsten Kulke, Global Innovation, Scent & Care Division, Symrise AG, Mühlenfeldstrasse 1, 37603 Holzminden, Germany.

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