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How to Create "A New Plastics Economy"? Marketing Strategies and Hurdles – Finding Application Niches

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14.1 Introduction

As was already thoroughly discussed in the previous chapters, the world anno 2021 seemingly has sufficient innovative ideas, (bio)chemistry researched, and novel materials prototyped which offer all the necessary bricks to start building the new plastics economy. However, the bottlenecks for bringing an idea or concept from the tech lab to a viable product in the market are manifold: after technicalities are tackled, it comes down to the wider business context such as production equipment (CAPEX), production capacity, economy of scale, marketing, intellectual property rights, and all of this in a rapidly changing legal framework. The social impact of new (bio)chemistries and material products cannot be overlooked. Debates about plastics and their use are appearing at all levels in social media. The awareness about old and new, about polluting and safe, about depleting and sustainable, is growing continuously – from expert to private consumer. And that is a positive trend: we have been tapping into the apparent richness and force of the fossil bubble, but many limits are coming up at an accelerated pace. The big words are out: biodiversity turns into mass extinction, a stable climate turns into uncontrolled tipping points, not to say that pandemic outbreaks are catalyzed by our ultra-global ways of acting in our business as well as private settings. The plastics industry is closely linked to many of these elements – in an increasingly holistic way.

This chapter discusses the business and socio-economic context of the various technical solutions discussed throughout this book: how to transfer viable products from concept to real products participating in tomorrow's new plastics economy? If we want to sustain the historically peaking living standards that many highly developed regions on the planet enjoy today, we need to transition to an industry that supplies the materials to support this situation in a sustainable way. Although there is common sense that this should happen, the road is paved with many challenges. As the attention for the plastic pollution grows, it seems these challenges will

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and are to be overcome by an expanding group of successful teams and companies around the globe offering sustainable solutions and finding their way to the market.

14.2 Stories from the Past

Starting from a breathtaking kick-off of the fossil plastics industry back in the 1930–1940s of the twentieth century, the industry considerably changed its rules over time. Some 80 years later, the industry has become massive. Investments have risen accordingly, and market leaders are confronted by ever-diminishing margins that can only sustain profitability via their often-depreciated mega plants. Exploration turned into maintenance and expansion: more of the same. “Incremental” has become the name of the game. Economy of scale has been ruling. Based on the past, it has become clear that more than a decade is needed to launch a new polymer – from discovery till full commodity. The driver for change has been decreasing over time because the fossil generation of plastic materials has been maturing and optimizing till unseen heights: in the framework of the fossil era they just work great.

However, the framework is changing nowadays. “Green” is rapidly shifting from *nice to have* to *need to have* and is becoming part of the business case. If big brands tend to follow their customers, and these customers want to live sustainably, the direction becomes very clear. As a consequence, the common sense about “green” is being sharpened at a fast pace: in life-cycle assessment (LCA) expertise all over the world, in legislation focusing on sustainability, and – not to underestimate – via social media and daily exposure to everyday products. In that sense, humanity is entering a new awareness era: “If we do not control our resources and waste, we cannot sustain our current wealth.” Finding the materials and their production processes that match this new reality is one of the important challenges to overcome. The many examples in this book give us a positive technical outlook, albeit not as mature as other green developments such as solar or wind energy. Though the challenge for new sustainable plastics also goes beyond technology, the examples below prove that all parameters of the business context should switch to “green” too before a new biomaterial finds its way to the market.

14.2.1 Polyhydroxyalkanoates (PHAs)

Although massive cumulative R&D budgets have been spent on polyhydroxyalkanoates (PHAs) over the last three decades, their breakthrough has still not fully happened so far. Though renewed production promises have been made in the recent years, PHAs have long suffered from a few disadvantageous characteristics:

- They often come with complex purification – adding to cost
- They often have the characteristics to crystallize slowly upon processing
- Once they solidify fully, the natural polyhydroxy butyrate (PHB) variants tend to become brittle.

Many of these persistent technical flaws have been largely overcome in the developments of the last decade (Chapter 6 on PHAs). However, also other elements have blocked the introduction of PHAs for several decades. It is clear that the business factors have been interwoven with the technical flaws. Historically, the cost perspective of PHAs has been stuck in suboptimal growth efficiency of the PHA-producing microbial strains, and their harvesting from the microbial biomass. The most important hurdle for their entrance into the market might have been caused by their cumbersome processing: when conventional equipment and conditions are used, PHAs in their natural form tend to underperform vs. established fossil plastics such as polyethylene and polypropylene, while their cost outranges these polyolefins by far. In other words, the balance in cost – functionality – ecology has not been favorable enough to promote their market entrance. Over time, both technical improvements and business attractiveness for introducing bioplastics have increased the marketability of PHAs. Examples of companies producing commercial and specialty PHA materials are Bio-on, Danimer Scientific, Eggplant Srl, Kaneka, Pharadox, RWDC Industries, and TerraVerdae Bioworks (http://www.bio-on.it/index.php; https://danimerscientific.com; http://www.eggplant.it; www.kaneka.co.jp/en; https://pharadox.com; https://www.rwdc-industries.com; https://terraverdae.com).

14.2.2 Polylactic Acids (PLA)

Polylactic acids (PLA) have also built up a multidecade history in the bioplastics industry, starting in the late 1980s. They found their way to the first kilotons since 2010 after almost two decades of specialty applications. Nowadays, their low-cost profile combined with their food-contact certification allowed them to enter in food packaging markets, such as thin films. However, their intrinsic properties also caused popularity dips, such as deforming coffee cups when containing hot liquid (because of a low crystallinity degree combined with a glass transition temperature of about 50 °C – lower than hot coffee or tea) or unpleasant crisping of chips bags – even the sound of bioplastics has turned them at some moments against their swift market uptake. Not helping their reputation, often the “biodegradable” label had been claimed for PLA, already since the time biodegradability was not yet documented very well: often they have been found in leftovers of industrial composters. Indeed, their biodegradation is proven but is generally not fast enough to guarantee disintegration and full mineralization in an industrial composter. Since some leading companies have upscaled PLA production and the launching applications have been saturated over time, the more than three decades of business development with PLA materials have led to a mature business with strong growth figures. Commercial PLA materials are produced by Corbion, Floreon, NatureWorks, and Ricoh-PLAir (http://www.corbion.com; https://www.floreon.com; https://www.natureworksllc.com; https://industry.ricoh.com/en/plair). Mixtures of both PHA and PLA are also used in commercial materials, for example at Bioplas Plastic, GoodNaturedProducts, Nonoilen, and Vegware (www.bioplas.com.au; https://goodnaturedproducts.com; https://nonoilen.com/en; https://www.vegware.com/uk-en).

14.2.3 Polyethylenefuranoates (PEF)

As a final example, polyethylenefuranoates (PEF) as a plant-based, recyclable, and degradable alternative for the widely used polyethylene terephthalate (PET) bottles have been largely discussed in literature [1]. They have been picked up by several parties in the market. Starting from fructose-rich or fructose-yielding sugar streams, several pathways have been explored and piloted. Avantium has been marketing PEF as the outperforming sustainable solution to PET as they developed and patented the YXY technology platform, converting fructose into furandicarboxylic acid (FDCA), and have established partnerships with several big brands, e.g. with Coca-Cola, L'Oréal, and P&G under the Paper Bottle Project (https://www.avantium.com/technologies/yxy). Next to Avantium, Corbion has developed a proprietary process to produce 2,5-FDCA as plant-based monomer for PEF and works on implementing this building block into the value chain of partners (http://www.corbion.com/bioplastics/fdca). After the discovery of an efficient and fast method for PEF production at the ETH Zürich, Sulzer now works on this proprietary ring-opening polymerization (ROP) technology for implementation in industrial mass production [1] (https://www.sulzer.com/en/shared/applications/polyethylene-furanote-pef). Still, however, after a decade of efforts toward the commercialization and market introduction of PEF, no PEF bottles are yet commercially available on the market in 2021. This shows that even with a strong technology and with powerful partners, the swift introduction of a novel and long-awaited biopolymer into the market is not guaranteed. Still, all of the above companies and partnerships pave the way toward a new plastics economy.

14.3 Greenwashing vs. Growing Pains

Almost together with the birth of sustainable initiatives, the term "greenwashing" has appeared, and its resulting perceptions have been growing alongside the development of green alternatives. The phenomenon has been discussed by researchers from various sectors, e.g. business, communication, and sciences, and is commonly described as a deliberate corporate action with the presence of misleading elements, focused on the deception of stakeholders [2]. In the race toward zero-waste and zero-plastic commitments, companies have been forced to make promises in their sustainability campaigns that they could not keep up with in following sustainability reports [3]. Although it can be questioned if it is better to break promises than not to make any promises of efforts toward a more sustainable planet at all, it all comes down to the same result: companies do not meet the goals set which leads to consumer distrust. Often established plastic producers are stuck in conservative systems and invested production assets that do not allow fast implementation of sustainable visions and missions, let alone products and materials. To maintain a clean brand name, however, their marketing branch is pushed to promote their good intentions. Unfortunately, the rigid back offices, ruled by many structures, cannot live up to the goals set or claimed commitments and hence many companies are trapped into the greenwashing pitfall. Often, still, the story does not stop with their inability to deliver but continues with hidden corporate actions to stop legislation or pushing responsibilities to consumers.

Ways to overcome greenwashing and initiate global steps forward involve all stakeholders. Policymakers should introduce policies, bans, and taxes with extended producer responsibilities, while companies need to focus on supporting legislation, transparency, and reduction in the use of resources, and consumers have to stick to several *R-words* of waste management – refuse, reduce, reuse, repurpose, recycle – while consciously supporting legislation [3].

Despite this, one should also recognize that greenwashing accusations have followed on genuine intentions of innovation that could not be realized due to one of the many obstacles on the unpaved road toward the new plastics economy – even by very thought-out strategic teams in big corporates. This is counter to the argument on intentional greenwashing and can be attributed much more to "growth pains". After all, it is important to also ground these allegations scientifically and consciously analyze them accordingly. Misperceptions due to poor scientific backing or bad marketing can lead to false accusations of greenwashing and unjustified greenwashing complaints. The European Single Use Plastics (SUPs) Directive, for example, is a reasonable initiative to reduce the use of (sometimes non-essential) SUP articles. Still, the corresponding attention obtained can lead to misperceptions on the environmental impact of these articles compared to other LCA elements in other single-use products. For instance, the food inside a plastic packaging is usually accountable for a larger environmental impact than the packaging itself: food supply might here be a decisive element in the overall LCA [4].

Finally, it is easy to accuse a company of greenwashing, but it is then very hard for the accused company to lose that stamp. Companies, small medium enterprise (SMEs), scale-ups, and start-ups cannot be perfect from the start in their urge toward the new plastics economy. Before pointing a blaming finger, one should consciously analyze the efforts done and steps taken in the right direction – where proportion is key and should be balanced out. If a market leading company is only offering 5% of its effort toward sustainability, and it cannot fulfill 90% of the goals set, we have more reasons to criticize than blaming a start-up that is fully focused on the development of bio-based materials (i.e. 100% effort) and has been missing 5% of its commitments. Companies should act fast, cluster their competences, trust each other, and advance in the right direction but should also be given the liberty of making acceptable mistakes when doing so. It is still a lot better than doing nothing at all.

14.4 From Idea to Product: "Technical Readiness Levels"

14.4.1 Defining the Technical Readiness Levels

Since companies have started to "re-invent" themselves and have focused on renewing their customer base in view of a more sustainable future, the innovation process has received increasing attention. In this paragraph, the process to introduce novel products in the bio-based materials markets will be explained along the so called "Technical Readiness Levels" (TRLs). In the meantime, the language to describe the different levels has been standardized in subsidized innovation programs on a national up to continental level, such as the Horizon Europe Program in Europe and National Science Foundation in USA.

To indicate the status of innovation from idea to product, the following definitions described below apply for each TRL, unless otherwise specified. Additionally, to clarify its use, we apply the list to a *typical innovation pathway in bio-based materials* running from TRL1 to TRL9 according to proper expertise in leading innovation projects that are handed on a daily basis – as at the moment of auditing, both authors are participating in 11 national and European innovation projects developing novel biomaterials:

- TRL 1 – basic principles observed
  "The idea" (virtual = in minds or on paper)
- TRL 2 – technology concept formulated
  "Making the idea generally understandable and partially confirmed" by showing a proof-of-principle
- TRL 3 – experimental proof of concept
  Demonstrate minimal lab results that support the idea: mostly mg to g scale experimentation with analytical detection of target compounds or materials
- TRL 4 – technology validated in lab
  Develop the minimal results to a robust lab protocol that can be repeated and gives first sample material: mostly up to 1 kg
- TRL 5 – technology validated in (industrially – in the case of key enabling technologies) relevant environment
  Transfer the protocol out of the lab into a pilot plant that represents a miniaturized form of the characteristics of a full-scale production plant: mostly to produce the first 10–100 kg
- TRL 6 – technology demonstrated in (industrially – in the case of key enabling technologies) relevant environment
  Further upscale in similar miniaturized equipment up to 1000 kg, giving access to "demo sample material"
- TRL 7 – system prototype demonstration in operational environment
  The demo sample materials attain a "minimal viable product" label since it can be validated and certified on industrial processing equipment in-house or at partners: the sample material is converted and validated into downstream products
- TRL 8 – system complete and qualified
  The parameters of the demo production plant are fixed and ready for transfer to a full production plant
- TRL 9 – actual system proven in operational environment or in competitive manufacturing in the case of key enabling technologies
  Launchable production samples can be produced in a production plant

TRLs go hand in hand with time and budget consumption. If we compare three TRL clusters from TRL1 to TRL9, we can differentiate as follows:

- TRL1–4: lab scale up to 1 kg, often one to three years R&D, between 10% and 20% of the total R&D budget
- TRL5–6: pilot and demo scale between 10 and 1000 kg, often one to two years R&D, between 25% and 75% of the total R&D budget
- TRL7–9: validation and certifications of pre-production samples, often about one year R&D, between 25% and 50% of the total R&D budget.

Many innovative bioplastics companies make use of an objective stage gate process, to reach consensus about positioning innovative leads in the pipeline, and to control innovation costs and risks. Most often, cross-departmental evaluations are organized to guide the innovation process (R&D – marketing – sales – purchasing – production). The aim is to position each innovation lead in the pipeline of upcoming novel products. Criteria set by the different departments are very important to prioritize the innovation budget. This in its own indicates that bringing novel bioplastics to the market, goes far beyond technology alone. The balance between the anticipated market potential of the lead, its risk profile, and its uniqueness is a determining factor to shift innovation leads up or down in the pipeline, leading to higher or lower TRL levels.

14.4.2 Application of the TRLs

In this budgeting exercise and the used criteria to shift innovation leads up and down on the priority list, innovation opportunities can be categorized along different parameters. Generally big corporates tend to promote more de-risked opportunities that can have substantial impact by their high volume, in return for the required investment. At the other side of the range, start-ups accumulate high risks in their opportunities and search the impact more in the disruption of the market to change the rules of game. This might also require high investments, leading to a whole new investment world from *angel* to *venture* to *corporate* investors, besides increasing subsidies, awards, and governmental support in general. In that sense, disruptive start-ups and big corporates come ever more in a symbiosis with each other, handling other but complementary risk parameters to guide the innovation opportunities. Even more, many start-ups increase their credibility by linking their innovation to established companies in the field, while the latter are stimulated to scout for disruption at start-ups. They are searching and finding each other more and more.

Though the DNA of big corporates and start-ups shows a substantial psychological difference: most big brands state "to follow their customers," while start-ups choose rather "customers to follow them." No doubt the latter is by far the strongest guarantee for radically new products, but the chance of success of customers following an unknown brand is indeed much lower. This plays an important role, even nowadays, in the plastics industry since the experience on bioplastics stretches broader over the value chain. With block chain technology and increasing traceability methods throughout the chemical industry, people will gradually gain understanding about where their materials come from and what it is. These insights will help them to fulfill their unmighty feeling of how to contribute to a sustainable plastics industry by making responsible choices. The value linked to these new insights will further determine the popularity of certain bioplastics compared to others. The hidden times for chemicals and plastics will soon be over: consumers have the right to know where the materials come from, who has made them, and if they fulfill their needs and desires. In that sense, the plastics industry can follow the paths taken by the food industry, where traceability has reached higher standards.

Regarding budgeting innovation opportunities through the TRLs, there are more common cost differences between running or starting big and small businesses. If we spread our thoughts over the innovation funnel, we must reach out from TRL1 to TRL9. In the ideation and discovery phase, up to TRL3, costs are highest in human capital and lowest in CAPEX. Typically, in this phase, a highly innovative research team is active in state-of-the-art labs. Today, these research crews are surrounded with innovation partners, which require competences like project management, human resource management, and IP management to run the cooperation. Already in this phase, relations are built up with investors and banks, subsidy agencies, governments, and schools. In socially driven research teams creating breakthrough companies, society is involved in all its facets already from the beginning onwards. Human resources also play an increasingly important role: employees search much more nowadays than a solid salary package. In this stage, with the help of subsidy support and angel investors for disruptive innovation, new projects can root at the start of the innovation funnel. It is important to create sufficient supporting "family, friends, and (a lot of) fools" (FFF) to try out apparent crazy innovations.

Once reaching TRL4–5, CAPEX increases considerably to prove that the novel product can be viable in an industrial environment. Pilot equipment is designed, invested in and/or finetuned to confirm the novel material in a scale most often situated between 10 and 1000 kg. Here, the focus lies on safety measures, robustness, accurate monitoring of process parameters, and achieved purities of target materials. Angel investments switch more and more to venture and corporate private equity in a so-called round A, which corresponds nowadays with a single-digit million investment. During TRL6, ending the development phase, early calculations for pricing and LCA become more reliable because of the industrial conditions of the trials. It prepares for the last part of the innovation funnel: TRL7–9 (representing demonstration and deployment).

At the end of the innovation pipeline, production and market launch are further prepared, involving security of supply, certifications, batch repetitiveness studies, quality and control (Q&C), energy and raw materials balances, demo materials for marketing campaigns, and optimizing production protocols. Also maintenance schemes are being scheduled and installed. Depending on the equipment that can be used for future productions, this stage can be either relaxed in CAPEX (when equipment is installed with free capacity) or become very CAPEX intensive when unique equipment must be designed, tested, engineered, and newly constructed. Once reaching this last part of the innovation funnel, it is necessary to plan production and capitalize for it. This is the time for investment rounds B and C rising in a double- and sometimes even triple-digit million investment nowadays, respectively. Going hand in hand, the employee number is rising along in the double- and triple-digit volume. Worth to mention: from this point onwards, green field installation of new production units requires most often at least two years to become operational in the plastics industry, while the chemical industry is one of the most CAPEX-intensive market sectors throughout the industry.

14.4.3 Product(ion) Validation

Once we design and scale novel bioplastics, product validation and certification might pose a challenge. Often plastic granulate-processing equipment is not fit to accommodate novel plastic grades. Otherwise extra investments are necessary to tune the equipment to reach acceptable processing conditions. Also, a novel plastic must overcome the maturity level that is often obtained for established fossil plastic types. Specification sheets have been created decades ago for the established plastics: it remains a challenge for new plastic types to match these requirements and meet all expectations from the beginning onwards. Processors or brand owners should be intrinsically motivated to overcome these hurdles, being patient and trustful that all necessary parameters can be sufficiently tweaked till a satisfying level. Also analytics and polymerization (bio)chemistry should be engineered in such a way that they can pivot further toward the desired key requirements – if achievable at all. Besides validation, certification is often required for novel plastic types. From biodegradation to food contact to registration, evaluation, authorisation and restriction of chemicals (REACH) certifications: all take time and budget. This all adds up to the overall risk that should be considered. A certification can be fully derisked, but can mean that the innovation falls out of its optimal time window to enter the market. Candidate world-leading innovators in the biomaterials sector that request too much certainty on a technical or economical level early onwards are in that sense mostly not the pioneers and frontrunners in their field. Being a pioneer means that you are prepared to pay the price of taking calculated risks – which can fail. Only companies with this truly innovative DNA get a long-term competitive edge and are trendsetting. Sometimes, in this respect, there is a discrepancy however between receiving credits and accumulating cash by pioneership.

Many companies use stringent multidisciplinary protocols to shift innovation leads from TRL1–3 to TRL4–6 to TRL7–9: a lot of innovation budget can be saved by selecting the best risk-mitigated set of leads to promote them to next TRLs in the pipeline. "Fail fast" is a beneficial competence in innovative companies, since "fail slowly" simply costs much more innovation budget.

14.5 Five Innovation Rules to Create "A New Plastics Economy"

Companies and company cultures grown in the fossil era have several characteristics that are challenged by the current transition to a bioeconomy. That is certainly also the case for the transition within the field of biomaterials. In this paragraph, we will highlight five attitudes that are not evident in the often-rigid structures of big corporates, but that are proving increasingly successful to bring novel biomaterials from idea to innovative product in the market. Below, we list five rules for an optimal innovation culture at biomaterials disruptor companies nowadays – the antagonist behavior of standard material companies that have grown to market leaders in the fossil era.

14.5.1 Target Small-Volume, High-Value Applications to Open New Market Space

New materials can go big, but not from day one. Actually, every material starts from scratch, from an idea and a first gram. Often that evokes an extreme exercise in humility for scientists and investors that aim for big impacts – but have to start from the first grams and kilograms onwards. That is how polyethylene and polypropylene were created, the blockbusters of the (mostly) fossil plastics industry today. It is also how it is expected to proceed for the winning biomaterials of the new plastics economy. *If we would know who they are (these winning biomaterials), they would exist already at big scale.*

There is a general tendency to call something "big" when it is big in relation to the company where the idea originated and development takes place. For big corporates, that amounts to substantial business, whereas for scale-ups it can mean a novel business with rather limited revenues. Also here, "big" is a relative measure. For each product class, optima and thresholds can be calculated where margins are optimized and highest business profitability is obtained. This indicates for each market segment what should be called big or small. An example is found with the PET business that flourished worldwide in the 1950s and 1960s via batch-line processes of several *kT* plate capacity each. It allowed to produce in a flexible manner and develop specialties to reach higher margins. Though when massive PET production facilities were built as from 2000 onwards, these flexible plants lost their competitiveness because their lower scale brought non-competitive fixed costs. In other words, what was big enough to run in the 1950s became too small to survive in the same business less than 50 years later. This sweet spot has to be determined for each biomaterial – of course one has to rely on assumptions if the market is even still under construction.

An example for this is found in the massive trials of Avantium to launch FDCA and PEF on the market. To reach its goals, the company has received major investment capital to aim "big" for PEF production with its technology estimated at a market worth of over US$ 200 billion [5]. However, in this case, apart from finding the sweet spot about volume, the competition with conventional PET that is increasingly recycled, has been shown to be tough.

A further consideration about scale is given in the following thought. When expanding and debottlenecking chemical and plastics sites, specific fixed costs drop considerably. One could therefore argue why not to make one very big production site for every chemical or plastic that is existing – covering the world capacity for that chemical or plastic from one central point on the planet: "One production site per plastic type." The answer is simple: at a certain moment the transportation to bring raw materials to the site and to get the resulting plastic products away from the site outweighs the gain in specific fixed costs. That means that economies of scale will always be limited by logistics. In a bio-based plastics industry where most raw materials evolve into bio-feedstock, these limitations become more stringent and follow completely other rules. Even more, biomass is growing because "every square meter on earth" receives an equal amount of sunlight and CO_2, besides different nutrients and soil or aquatic conditions to determine the overall fertility package on each local spot. Biomass growth is therefore organized in an extremely decentralized way by nature since almost four billion years of evolution. Consequently, the most efficient bio-based plastics industry is also partially decentralized. This means that transitioning from a fossil to a bio-based industry comes with spread-out production sites following other rules in economy of scale.

And then there is the eagerness to (be able to) predict which material will go big. How many innovative pipelines have been managed from the risk-balanced "calculation" that *they would go big*? And how many times has reality confirmed this calculation? Predictions on how big novel materials can go in the market are seldomly proven accurate and therefore can rather be considered as hypotheses instead of predictions. Just as the target application only becomes clear after thorough test programs, the size of the market can only be estimated after sufficient validations and certifications – mostly an accumulation of many trials and adjustments. And that brings us to the second dogma.

14.5.2 Time Right Instead of Fast

Besides going big, most business plans want to take control of time. If there is one parameter that is hard to control, it is the exact timing to drop the innovation in the market. That is because many elements that open the opportunity window for launching a new biomaterial go far beyond the technical influence of a single company. Nowadays, the rhythm of biomaterial innovation is determined by multiple effects, some hampering, others stimulating the speed of development:

– the supply of sometimes seasonal- and climate-dependent renewable resources
– the production capacity to convert them into bio-based building blocks or materials
– the timing to design and construct novel production equipment for novel processes
– a lacking driver for change in application fields that match with the material properties
+ invested money that awaits return on investment
+ time-ticking patents and IP in general
+ media attention that creates unplanned momentum
+ consumer surveys and social media that push the transition.

Again, "fast" should be seen related to the context where the innovation has to happen: big corporates are generally impactful but slower, while start-ups and scale-ups start from scratch but can handle in a very agile way. When we talk about innovating with intrinsic novel materials containing new molecular backbones, there is again a common understanding about what is fast or slow. While the beginning of the fossil plastics industry has been characterized with swift developments, the innovation speed has been slowing down considerably after half a century. For instance, several historical leading European chemical sites, such as the BASF site in Ludwigshafen (Germany) and the Brightlands Chemelot site in Geleen (The Netherlands), have been built at the speed of one to two production plants per year shortly after World War II. By the end of the twentieth century, this speed went down by about one order of magnitude – till plants even got transferred in mothballing status, which is a controlled shut-down of a chemical plant to anticipate for its smooth restart later in time, or were even dismantled (https://www.basf.com/global/en/who-we-are/history/BASF-History-in-Figures.html; https://www.chemelot.nl/chemelot-en/history). Because the market was saturated with "those very mature and cost-efficient fossil plastics," it became very challenging to introduce any new materials in the market. The ideas and developments to overrule current plastics were scarce and risky, and the market had no driver for change. This led to a general statement in market leading corporates that "entering a novel plastic on the market takes at least 10 years," which also seemed to be confirmed by the market.

But then some existential questions were asked and start-ups were appearing in the chemical industry at the start of the twenty-first century – mirroring the developments in the pharma sector since the 1990s [6]:

- *Venture funds came alive in the chemical industry through the following question*: "Do we still invent novel plastics ourselves, or do we look for successful start-ups and acquire the technology once it is de-risked?"
- *But especially in the case of bio-based plastics*: "Do we have the time to wait for 10 years to develop novel bioplastics that present less ecological concerns?"

Currently, typical breakthrough bio-based plastics developers are underway to transfer their innovative materials from TRL1 to TRL9 in less than five years, reaching multiton scale to even kiloton scale in a timeframe of less than seven years. The tendency is that this timeframe will be further reduced and will be fueled by the sustainability revolution that is currently climbing to unseen heights.

14.5.3 Go Local

Since neoliberalism, our sense for global activities is overdeveloped. Fossil energy and carbon sources have contributed to this globalism since they have made transport costs very low. We take it for granted that our pen is made from a plastic type containing carbon atoms that are originating from fossil resources harvested at the other side of the planet. In the fossil industry, it is normalized that a pen will travel easily 20 000 km to find our hands to write with it. If this looks eye-opening today, it might be labeled *unforgivable* by our children.

Of course, there is a reason why we are not aware or conscious about these global journeys: plastics have become too cheap and too anonymous to steal our thoughts and our precious time. In the Dutch language, another word for plastics is, literally translated, "Art-Stuff" but they leave an impression far from anything artistic. They are too common for that – they slash our brains – even more: we hardly remark their presence. How many car owners know that there is more than 300 kg of plastic in their vehicle, let alone where it would come from? Even the salesman of the next-door car shop has nothing in his value proposition that comes close to anything like plastics. Plastics, apart from their claimed recycling percentage, are simply hardly or not at all mentioned in the catalog, apart maybe from a few articles that you can touch in the interior space, such as grass-filled panels or a recycled dashboard strip. Their absolute minority is meant to neutralize any guilt feeling – and surprisingly it still does. But luckily not for long anymore.

This global attitude – also counting for other materials like metals or glass – that dominates the current fossil plastics economy, has grown over the last centuries but demonstrates to have an irreversible effect on our planet [5]. In contrast, technical developments show a very promising outlook to disrupt this ultra-global non-conscious model: they show that the carbon in bioplastics now can be much more local and renewable. This evolution is even stimulated by logistics that are prone to hit new price records. In the case of PLA for instance, the LCA can be significantly improved when the resources for this material are harvested and used close to the respective market. Bio-based materials lose their effect when they travel half the planet to reach their market: their proximity between creation and use is just a differentiator vs. virgin fossil materials.

14.5.4 Take Risks

There is another dogma that is rooted deeply into the maturity of the current plastics industry: "Why should we take risks if our fossil industry is (still) doing so well?" Indeed, the plastics industry will nearly triple in the next three decades only, driven by demand, hitting close to one billion ton of plastics production per year by 2050 [7]. This evokes a dilemma: should we disrupt the plastics industry in the coming years with novel materials, or pay the climate bills of a *supermature fossil plastics industry* exhausting close to one billion tons of plastics to the planet every year?

So far, novel biomaterials have shown that their popularity or profitability cannot be predicted. To know their fate, one still must go through that dark tunnel of uncertainty: entrepreneurship in balance with good financial control is the best recipe – gradually stepping up till the products have been de-risked. It goes hand in hand with launching novel bioplastic specialties, that, upon successful market introduction, hit lower costs as they scale, opening more market space. The path flows from the top of the plastics pyramid to sink to levels that balance out pricing vs. economy of scale. Moderating the rights steps along this path, with the right timing and sufficient patience, is the best risk mitigator one can wish for creating a new plastics economy. For start-ups, this means that (back)loans, bank credits, angel investments, and subsidies span the financial strength required for each of the steps to take. And although the path is unknown, dividing it in overseeable steps helps to keep upright and move forward.

14.5.5 Go "Green"

Another challenge for plastic materials is the length of their lifetime. We created a lot of fossil plastics, but hardly laid-off some. They are landfilled. They are linear. Comparing plastics with the history of life on our planet, it seems the young existence of plastics is in no sense in line with the success factor of life in general: "Survival of the fittest," in which circularity rules. Ironically, almost all plastics that were ever made are somehow surviving so far – if not burned to black carbon dioxide – but not in a way that is compatible with nature. Now, as new ecological trends are kicking into our lives in numerous ways, also plastics should move on toward more sustainability by changing the rules for their existence. The examples in this book show that many fossil plastics can be, apart from proper recycling, substituted in their applications with alternatives that make up for a new ecological way of fulfilling the desired functionality. In that sense, plastics and their uses are starting their second generation – the new plastics economy – in search for their ecological siblings that fit a modern sustainable society. None of them should be invented or launched to grow forever. They should only last until a new optimized product has been developed that is more beneficial to sustain all life on this planet.

There is another trend that dominates the fossil plastics industry: plastics should be high performing. In many cases, "high" performance can be substituted by "out" performance. Many plastics are even "over" performing for their application. This is in contrast again with nature: all materials that have been accurately optimized to build fauna and flora, and human beings, have never been selected based on their "out-performance." They just did perform *enough* for what they were meant for. And that performance also contained an ecological performance: bio-based content, biodegradability, and unlimited recyclability by breakdown to biogas and biomass. If we start to suffer from CO_2 exhaust and from microplastics, why would we continue to outperform in a classical way? The classical way where plastic production creates high levels of CO_2 in their production and logistics, and in their toxic end-of-life? Would we not switch "out" for "enough" and get sustainability in return? Because we tend to forget that "enough" has been the key word of natural evolution on Earth, just as Darwin's theory showed that the "fittest" was the one that was "fit enough" to survive.

Talking about fit enough, one can argue how to define it for plastics. In that sense, "perfection" and "standardization" became credos of the fossil plastics industry. In fact, both are in contrast with nature again. Perfection and standardization are forbidden terms to guarantee a successful evolution promoting *the fittest*. How can you even have a fittest under perfect standardized conditions – making only copies and clones? *Cloning is nature's sin*. Nature worked for billions of years to perfection of DNA-based life on Earth: the one that allows a seldom *error* in the DNA code, besides recombining the DNA all the time, to exactly create what makes a living community strong in the end: *diversification, supporting biodiversity*. No two trees, no two people, no two creatures on this planet are exactly the same, since diversity created diverse survivors that were fit to varying circumstances. So why could we not tolerate small imperfections, losing maybe some cost efficiency in the production but allowing much more degrees of freedom in molecular and article design of novel bioplastics? (https://www.plasticpollutioncoalition.org/blog/2017/5/2/10-inspiring-works-of-art-about-plastic-pollution; www.hanaadahy.com). Let us not fight against proven models from nature – let's be inspired by them. Maybe this degree of freedom injects a lot of fresh oxygen to bright minds, legislation and producers, to create and establish the new plastics economy. We will not create it by endless restriction lists, but by shaping opportunities with new materials. Let the selection criteria for bioplastic survivors not be ruled by the fossil plastics industry, but let them be reflected by a world that has the choice between sustainability or human extinction.

14.6 Conclusion

The message of the five dogmas above is as simple as uncomfortable related to the plastics industry: the continuation of the wellbeing of developed societies lies in the hands of consumers, besides disruptive teams in corporates, SMEs, and start-ups, often flanked by academia, trying out new technologies. Open innovation at its best. Ethical radars switched on. It has the character of a gamble. But one can argue that the risk not to gamble is becoming higher than gambling itself – for novel bioplastics that bring functionality together with affordability and unprecedented ecology. Once new materials hit a new balance in their application and become subjected to upscaling dynamics driven by demand, they start to gain the sympathy of innovators, believers, partners, and finally end-consumers. Unluckily for the pioneers involved, there is no guarantee on big or fast successes. There is also a limited tendency to search at the other side of the world what can be found and harvested locally. Certainties are not existing – they have to be created. And the growth of the innovative biomaterial might be moderate or even stop at a certain scale. These pioneers will also have to teach the world that enough performance is good enough, and *imperfection* is the new perfection. Besides scientists and industrialists, they should become an inspiration that is followed – realizing the dream of a sustainable world. If soldiers liberate(d) us from wars, and medicinal forces saved us from a global pandemic, let bioplastics pioneers and technology pioneers in general help to save us from the most urgent threat of all: climate change. As people will also have *to help themselves* based on intrinsic motivation for a more sustainable planet, the transparency and inspiring elements should be safely conceived in novel plastic types. The point is that the origin of this climate change is very clear: it is not originating from a lab, but from the cumulative exhausts of the unreasonable consumption behavior of the civilized population that calls itself "well-being" [8]. And since you are reading this book: chances are big that you are one of them. This means in turn that there is very good news: the impact of your new ecological life is potentially extensive and can start today. Just redesign your daily life, leverage your awareness, choose with responsibility, and *be for plastics* described in this book that guide us to new sustainable horizons!

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