Chapter 11
Solutions to Plastic Pollution: A Conceptual Framework to Tackle a Wicked Problem

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Abstract There is a broad willingness to act on global plastic pollution as well as a plethora of available technological, governance, and societal solutions. However, this solution space has not been organized in a larger conceptual framework yet. In this essay, I propose such a framework, place the available solutions in it, and use it to explore the value-laden issues that motivate the diverse problem formulations and the preferences for certain solutions by certain actors. To set the scene, I argue that plastic pollution shares the key features of wicked problems, namely, scientific, political, and societal complexity and uncertainty as well as a diversity in the views of actors. To explore the latter, plastic pollution can be framed as a waste, resource, economic, societal, or systemic problem. Doing so results in different and sometimes conflicting sets of preferred solutions, including improving waste management; recycling and reuse; implementing levies, taxes, and bans as well as ethical consumerism; raising awareness; and a transition to a circular economy. Deciding which of these solutions is desirable is, again, not a purely rational choice. Accordingly, the social deliberations on these solution sets can be organized across four scales of change. At the geographic and time scales, we need to clarify where and when we want to solve the plastic problem. On the scale of responsibility, we need to clarify who is accountable, has the means to make change, and carries the costs. At the magnitude scale, we need to discuss which level of change we desire on a spectrum of status quo to revolution. All these issues are inherently linked to value judgments and worldviews that must, therefore, be part of an open and inclusive debate to facilitate solving the wicked problem of plastic pollution.

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11.1 Premises and Aims

The scale of plastic pollution and its impacts on nature and societies has been extensively described and discussed in the public and the scientific literature (including this book). While there is much debate on the scale of the problem, the aim of this essay is to explore the solution space for plastic pollution. Therefore, this essay is based on the premise that the case is closed, in such that there is a board consensus that we want to solve it. The relevant question then becomes how to achieve best this. There is abundant literature summarizing potential solutions for plastic pollution (Auta et al. 2017; Eriksen et al. 2018; Löhr et al. 2017; Prata et al. 2019; Sheavly and Register 2007; Tessnow-von Wysocki and Le Billon 2019; Vince and Hardesty 2018). However, many authors focus on specific technological, governance, or economic aspects and some organize solutions in rather arbitrary ways. Such pragmatic collections are certainly useful to get an overview of available options. Nonetheless, they may fall short in addressing the complexity of plastic pollution (e.g., when they present few, specific solutions), the diversity in the perspectives of the multiple actors involved (e.g., when they focus on technological solutions only), and the fundamental aspects driving the preferences for certain solutions. Therefore, the aim of this essay is not to present another collection of technical and policy instruments. Instead, I will first explore the wickedness of the problem because it is important to acknowledge that there is no simple solution to problems that are difficult to define and describe. Secondly, I propose a conceptual framework regarding how specific problem formulations result in diverse and sometimes conflicting sets of solutions. Clarifying distinct problem frames is an important step toward understanding the actors' diverse preferences for solution sets. Thirdly, I lay out a framework for organizing the value judgments inherent in the plastics discourse. Since these are mostly neglected in the public and scientific debate, the aim of this piece is to bring to the surface the value-laden issues underlying the framing of the problem and the preferences for certain solutions.

11.2 Plastic Pollution as Wicked Problem

To contextualize the solutions to plastic pollution, we first need to explore its wickedness. The concept of wicked problems has been used to characterize those problems which defy conventional solutions, including climate change, displacement of people, terrorism, digital warfare, and biodiversity loss (Termeer et al. 2019). Originally introduced to describe "problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (Churchman 1967), Rittel and Webber (1973) provided ten characteristics that define a wicked problem, some of which are shared by plastic pollution (see Table 11.1). Since then, the simple dichotomy of tame vs. wicked problems has

Table 11.1 Characteristics of wicked problems and their applicability to the plastic pollution issue

Characteristics	Applicability to plastic pollution (author's opinion)
(1) Wicked problems are difficult to define. There is no definite formulation.	Yes, there is a diversity in framing the problem.
(2) Wicked problems have no stopping rule.	Yes, we will not know for certain if/when we have solved plastic pollution.
(3) Solutions to wicked problems are not true or false, but good or bad.	Partly, some specific solutions (e.g., stopping pellet loss) can be true. Other solutions require value judgement.
(4) There is no immediate or ultimate test for solutions.	Partly, effectiveness of some local solutions may be testable but is impossible to test for global solutions.
(5) All attempts to solutions have effects that may not be reversible or forgettable.	Unknown but possible, especially when considering the largely unknown environmental impacts of replacements.
(6) These problems have no clear solution, and perhaps not even a set of possible solutions.	Unknown, a broad set of solutions is available in theory or practice, but their potential to actually solve the problem is largely unknown.
(7) Every wicked problem is essentially unique.	Unknown, but strong commonalties of plastic pollution with other global change issues exist.
(8) Every wicked problem may be a symptom of another problem.	Yes, for instance, plastic pollution can be framed as a symptom of a linear economy.
(9) There are multiple explanations for the wicked problem.	Yes, see (1)
(10) The planner (policymaker) has no right to be wrong.	No, there probably is a margin of error, in such that multiple solutions can be tested without (much) regret.

Adapted from Rittel and Webber (1973)

evolved into a view that rather considers degrees of wickedness (Termeer et al. 2019). The question, therefore, is how much wickedness we assign to plastic pollution. The key features of complexity, diversity, and uncertainty (Head and Alford 2013) can be used to do so.

Without question, the issue of plastic pollution is complex, both from a scientific and a societal perspective (SAPEA 2019). The scientific complexity arises from a number of aspects. Firstly, plastic pollution comprises a diverse suite of pollutants with very heterogeneous physicochemical properties (Lambert et al. 2017; Rochman et al. 2019). Secondly, plastics have a multitude of sources, flows, and impacts in nature and societies. Thirdly, plastic pollution is ubiquitous, yet its scale varies in time and space. The combination of these aspects results in complex exposure patterns causing a complex suite of effects on biodiversity and human health, covering all levels of biological organization, as well as on the functioning of ecosystems and societies. To further complicate the matter, these effects will probably not be linear, immediate, obvious, and overt but will be heavily interconnected and aggregate over time scales that are difficult to investigate. Thus, the complexity of plastic pollution – and its underlying causes – cannot be understood with "standard science" based on disciplinary approaches and the assumption of simple cause-effect relationships.

The societal complexity of plastic pollution arises from the fact that plastics are – besides concrete, steel, and fertilizers – one of the main building blocks of modern societies (Kuijpers 2020). They are so closely integrated with many aspects of our lives that modern societies cannot function without plastics. Accordingly, the immense societal benefits of plastics arising from their versatility, light weight, durability, and low costs are very difficult to decouple from their negative impacts caused by just the same properties. The resulting ambiguous relationship of humanity with plastics (Freinkel 2011) in combination with the complex flows of plastics through societies constitutes the societal complexity of plastic pollution.

The public, political, and scientific discourses on plastic pollution are characterized by a high degree of diversity in such that actors take divergent, and sometimes conflicting, views and approaches to the problem and its solutions. Much of that diversity emerges from the fact that the discourse on plastic pollution, just like on many other environmental problems, is a value-laden issue. In such situations, actors will frame the problem and interpret the available evidence differently based on their specific believe systems, values, and agendas.

Finally, plastic pollution is characterized by a high degree of scientific, political, and societal uncertainty. This is not only true for the glaring gaps in our scientific knowledge (SAPEA 2019) but even more so for the nonlinearity and unpredictability of the impacts that plastic pollution (and potential solutions) may have on ecosystems, humans, and societies. As an example of scientific uncertainty, there might be tipping point at which the ecological consequences of increasing pollution might become chaotic and unpredictable. Another, very concrete example of political uncertainty is the need to balance unforeseen benefits of plastics (e.g., massive demand for personal protective gear in case of a pandemic) with the negative impacts of pollution. While continuing research efforts will eventually reduce the scientific uncertainties, "better" evidence will not necessarily reduce the political and societal uncertainty surrounding plastic pollution. This is because the diversity in actors' views and agendas routed in their individual values is unlikely to change when new scientific evidence arrives.

Taken together, plastic pollution comprises a relatively high degree of wickedness because it features scientific and societal complexity, actors with diverse and divergent problem/solution frames and goals, and a high degree of scientific and political uncertainty. Leaving aside the aspects of complexity and uncertainty here, it is worth investigating how divergent problem formulations result in a diversity in solutions and how value judgments inherent in the discourse on solution to plastic pollution can be conceptualized.

11.3 Problem Formulations: Consensus or Dispute?

On the surface, the problem formulation for plastic pollution seems quite straightforward. The accumulation of plastics in nature is a bad thing. Despite many scientific uncertainties, such a statement receives broad support from the scientific

community, the public, policymakers, and societal actors (e.g., interest groups) alike. Despite the absence of an overt and coordinated denialism, such as the one for climate change, a closer examination reveals that three aspects of plastic pollution are contested, namely, the risk paradigm, the scale, and the root causes of the problem.

There are two opposing views on what constitutes the risk of plastic pollution. The commonsense perspective is that the sheer presence of plastics in nature represents a risk. Such view is propelled by the attention economy (Backhaus and Wagner 2020) and the scientific uncertainties, in such that scientific ignorance ("we do not know the ecological consequences") becomes a risk itself (Völker et al. 2020). Even though empirical data are absent, this conception of risk is probably very common in the public and is promoted by environmental interest groups. An opposing perspective poses that there are thresholds below which plastic pollution will not be a risk. That more expert view comes from toxicological and regulatory practices which are based on Paracelsus' paradigm of "the dose makes the poison" and risk assessment frameworks to compare the exposure and hazards of synthetic chemicals. The main divergence between the two perspectives is that one claims that there is no "safe" threshold of plastics in nature whereas the other does. This is, in essence, a value-laden question because deciding whether we deem emitting plastics to nature acceptable is a moral, ethical, political, and societal issue rather than a purely scientific one. It may sound provocative, but on a systems level the actors benefiting from environmental action (e.g., environmental interest groups) pursue a "zero pollution" aim whereas the actors benefiting from continued emissions (e.g., plastic industry) push for a "threshold" view.

The scale of the problem of plastic pollution is also a matter of conflicting views, at least among academics and interest groups. This is best exemplified using microplastics as case. Some scientists consider the problem "superficial" (Burton Jr. 2017) and even "distractive" (Stafford and Jones 2019), whereas others consider it "significant" (Rochman et al. 2015) and "urgent" (Xanthos and Walker 2017). Without getting into the details of the different arguments, the main driver of the superficiality perspective is the assumption that environmental problems compete for limited attention and resources (Backhaus and Wagner 2020). Thus, we need to prioritize problems that are deemed more important (e.g., climate change). The opposing view poses that the microplastics problem is part of the larger issue of global change that cannot be viewed in isolation (Kramm et al. 2018) and argues that "we simply do not have the luxury of tackling environmental issues one at a time" (Avery-Gomm et al. 2019). Again, a value-laden question is at the heart of this dispute, namely, whether solving environmental issues is a zero-sum game that requires focusing on the few, most pressing problems or rather represents a win-win situation in which tackling multiple problems at once will yield co-benefits and synergies.

The last area of dispute is the question about the actual causes of plastic pollution. This is essentially a matter of problem framing that will have wide implications for finding solutions. For instance, framing plastic pollution predominantly as a marine litter problem will promote a completely different set of solutions (e.g.,

ocean cleanup activities) compared to a framing as consumerism problem that would require larger social changes. As with the two areas discussed above, individual values and belief systems will determine how one frames the causes of plastic pollution and which solutions one prefers, accordingly.

11.4 What Are We Trying to Solve?

Investigating the different conceptions of the causes of plastic pollution offers a meaningful way to organize the sets of solutions we have at hand. Importantly, that is not to say that one of the views is true or false but rather to understand why different actors prefer and promote divergent sets of solutions. To start with a commonality, the concerns about the impacts of plastic pollution on nature, human health, and societies are the drivers of all problem-solution frames. However, five different lenses can be used to focus on the problem formulation rendering plastic pollution a waste, resource, economic, societal, and systemic problem (Fig. 11.1).

Importantly, the lack of awareness about these frames can obscure the debate on plastic pollution. For instance, plastics are often used as a proxy to debate other societal issues, such as consumerism. Thus, seemingly scientific controversies become an arena to negotiate political and philosophical issues (Hicks 2017). This is problematic for two reasons. Firstly, scientific debates make a poor proxy for talking about value-laden problems because they are often technical and narrow and, therefore, exclude "nonexpert" opinions and economic and cultural aspects. Secondly, as Hicks puts it "talking exclusively about the science leads us to ignore – and hence fail to address – the deeper disagreement" (Hicks 2017). To make the debate on plastic pollution productive, all involved actors should transparently delineate how they frame the problem, be open to discuss the deeper disagreements

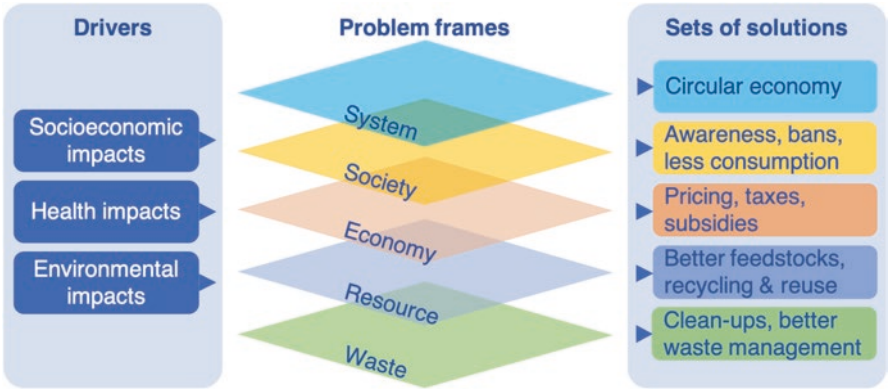

Fig. 11.1 Common drivers result in a diverse framing of the problem of plastic pollution and its causes. This determines the set of preferred solutions

that may be beyond the traditional scope of hard sciences, and be receptive to other arguments and viewpoints (e.g., the cultural value of an unpolluted nature).

11.5 Solving the Waste Problem

The most common approach to plastic pollution is to frame it as a waste problem. From that perspective, the main cause is our inability to effectively manage the plastic waste and prevent its emissions to nature. According to this view, plastic pollution basically becomes an engineering problem that can be fixed with a set of technological solutions.

While not preventive per se, cleanup activities on beaches, rivers, in the open ocean, etc. can be considered part of the set of solutions to the waste problem. Targeted at removing plastic debris from nature, these can range from low-tech solutions involving citizens simply cleaning up polluted places (e.g., organized by Ocean Conservancy, the Nordic Coastal Cleanup, or Fishing for Litter), to medium-tech solutions that collect debris before it enters the oceans (e.g., Mr. Trash Wheel, the Great Bubble Barrier), to high-tech solutions such as the large booms deployed by the Ocean Cleanup or remotely operated underwater vehicles (see Schmaltz et al. 2020 for a comprehensive inventory). Cleanup solutions can be criticized as ineffective and inefficient basically because they represent measures that are the furthest downstream of the sources of plastic pollution. Some technological approaches, such as the Ocean Cleanup booms, might even have negative consequences on marine biota (Clarke 2015). However, these activities may also have benefits that go beyond removing plastics from nature. Engaging volunteers in cleanup activities can increase their awareness of pollution and promote pro-environmental intentions (Wyles et al. 2017, 2019) that may result in a more sustainable change in behaviors.

Improving waste management is at the center of the set of solutions associated with the framing as waste problem. The goal of these activities is to minimize the amount of mismanaged plastic waste "escaping" to nature. The waste management sector in the Global North faces serious challenges, such as infrastructural fragmentation, lack of capacity, and the inability to deal with increasingly complex plastics materials and waste streams (Crippa et al. 2019). Taking the European Union as an example, there is a need to better implement and enforce existing waste legislation, harmonize waste collection, and promote innovation regarding new business models and waste sorting technologies (Crippa et al. 2019). However, most of the worlds' mismanaged plastic waste is emitted in the Global South (Jambeck et al. 2015) with its predominantly informal waste sector where autonomous and organized waste pickers are highly skilled participants in local circular economies. Reconciling their livelihoods with aspirations for industrial automation remains a challenge, and external intervention attempts will likely be unsuccessful without sufficient local capacity building (Velis 2017). The Global North can support such development by sourcing recycled plastics from the informal recycling sector,

thereby gradually formalizing this sector (Crippa et al. 2019) and creating socioeconomic benefits for waste pickers (Gall et al. 2020).

Another dimension to look at plastic pollution is the global trade of plastic waste. More than half of the plastic waste intended for recycling has been exported to countries other than the ones producing the waste (Brooks et al. 2018). In the case of the European Union, most exports have been directed toward the Global South (Rosa 2018) with notable shifts since China restricted waste imports in 2017 (European Environment Agency 2019). The concerns over this practice arise from the fact that recipient countries often have low labor and environmental standards resulting in occupational risks and improper waste disposal or recycling (World Economic Forum 2020). In response, the 187 member countries amended the Basel Convention, an international treaty on the transboundary movement of hazardous wastes, to better control the global flows of contaminated, mixed, or unrecyclable plastics (Secretariat of the Basel Convention 2019). While this is promising, the Basel Convention is limited regarding its ability to enforce compliance and monitor progress (Raubenheimer and McIlgorm 2018).

A third approach to tackle the waste problem is to increase the production and use of compostable or biodegradable plastics. The expectation is that such materials will disintegrate on short time scales either in industrial and household settings or in the environment (Crippa et al. 2019; Lambert and Wagner 2017). Compostable and biodegradable plastics would, thus, contribute to decreasing the amount of persistent plastic waste and create biomass to amend soils. While a range of biodegradable plastics from fossil as well as renewable feedstocks is available, their market share remains low, making up less than 0.5% of the global plastic production (Crippa et al. 2019). This is mainly due to their high costs (compared to a limited added value) and technical challenges in scaling up production capacities. Additional challenges arise from misperceptions and misrepresentation regarding what biodegradable plastics can achieve (Crippa et al. 2019, see also the example of oxo-degradable plastics), from a low degradability of available materials in nature, and from the lack of transferability of degradation data from laboratory to field settings (Haider et al. 2019).

Importantly, when choosing to frame plastic pollution as a waste problem, the principles of the waste hierarchy apply that clearly prioritizes the prevention and reuse of waste over its recycling, recovery, or disposal (European Parliament & Council of the European Union 2008). However, contemporary solutions to the plastic waste problem mainly focus on less preferred options, especially on recovery and recycling. As an example, the European Strategy for Plastics in a Circular Economy (European Commission 2018) contains the terms “prevention” and “reuse” only 8 times, each, while it mentions “recycling” 76 times. A reason for that preference might be that the technological approaches to recycling, recovery, and disposal exist within the waste sector, whereas approaches to reduce and reuse plastics would require the inclusion of very different actors, such as social scientists and designers.

11.6 Solving the Resource Problem

Framing plastic pollution as a resource problem is based on the idea that we are losing valuable materials when using plastics in short-lived products, such as packaging and single-use items. Such framing is closely connected to the waste problem as waste management is transforming into resources management. In a broader context, however, this idea can be reformulated as a problem of extractive fossil industries in such that the cause of plastic pollution is indeed the abundance of fossil feedstocks. Both aspects of the resource framing result in divergent sets of solutions.

Approaches to solve the resource problem from a waste perspective basically cover the upper parts of the waste hierarchy, namely, recycling and reuse. The rationale is, of course, to retain the material and functional value of plastics in use and extend the lifetime of materials or products. This would, in turn, reduce waste generation and the need to produce new plastics. The different options fall on a spectrum on which reuse and mechanical recycling preserve best the value of plastics because they avoid the extra costs for breaking up the materials (Fig. 11.2). In contrast, chemical recycling uses chemical or thermal processes (e.g., depolymerization, pyrolysis, gasification) to create purified polymers, oligomers, or monomers which then can be reprocessed into new plastics. This has several advantages over mechanical recycling, such as the higher flexibility and the ability to deal with mixed and contaminated plastics. Nonetheless, chemical recycling currently requires significant improvement regarding their technical and economic feasibility as well as a thorough investigation of its environmental and social impacts (Crippa et al. 2019).

In contrast to set of solutions provided by the recycling plastics, retaining plastic products in use via sharing, repairing, and reusing comes closer to a circular economy ideal. While circular business models for plastics suffer from the lack of economic incentives (see economic problem), the four current types of business models include product as a service ("pay-per-use"), circular supplies (waste of one company becomes the raw material for another), product life extensions (making products durable, repairable, upgradable), and sharing platforms (Accenture 2014).

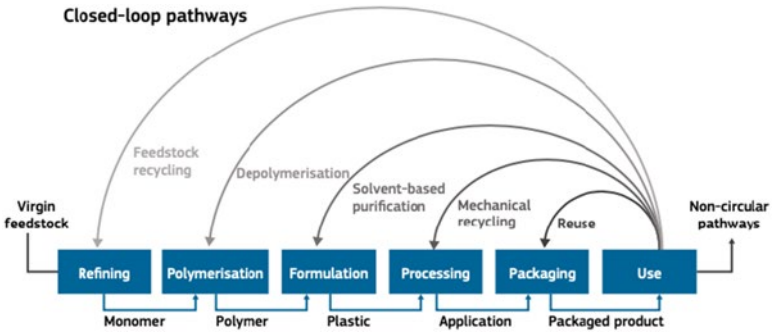

Fig. 11.2 Different loops for the reuse and recycling of plastics. (Source: Crippa et al. 2019)

Such approaches face challenges not only because plastics move so fast through the value chain and are handled by multiple actors but also because they challenge the linear economy paradigm. Here, eco-design guidelines and circularity metrics can help create a more level playing field (Crippa et al. 2019).

A very different solution, namely, the shift to bio-based plastics, emerges when framing plastic pollution as a problem of fossil feedstocks. Here, the idea is to reduce the use of petroleum and natural gas to manufacture plastics and foster the transition to a bio-based economy. Bio-based plastics can be produced from natural polymers (e.g., starch, cellulose), by plants or microbes (e.g., PBS, PHA), and by synthesizing them from biological feedstocks (e.g., ethylene derived from fermented sugarcane) (Lambert and Wagner 2017). As with biodegradable plastics, the market share of bio-based material is rather low for economic reasons, but production capacities and demand are projected to increase in the future (Crippa et al. 2019). The main challenges of shifting to bio-based plastics are their potential environmental and social impacts associated with land and pesticide use. These can be addressed by using feedstocks derived from agricultural, forestry, and food waste as well as from algae (Lambert and Wagner 2017). Eventually, substituting fossil with renewable carbon sources is a laudable aim that can create many co-benefits. However, it is important to realize that this will not solve the problem of plastic pollution.

11.7 Solving the Economic Problem

A very different perspective on the discourses on plastic pollution is the framing as an economic problem. As discussed above, many solutions are not competitive in the marketplace due to their high costs. Accordingly, the low price of virgin plastics which is a result of the low oil and natural gas prices can be considered the major cause of plastic pollution. Taking such view implies that one major benefit of plastics – their low price – is driving consumption which, in turn, results in their emission to nature. It also dictates that solutions should address the economy of plastics.

The goal of economic solutions to plastic pollution is to reduce plastic consumption either directly via financial (dis)incentives or indirectly via creating a level playing field for other solutions, including alternative materials (e.g., bio-based plastics), recycling, and circular business models. The simplest and most widely adopted economic instrument is to place levies on single-use products, especially on plastic bags. For most cases, increasing the price of carrier bag reduced the consumption but the global effect of such policies remains uncertain (Nielsen et al. 2019). In addition, there may be unintended consequences and the ecological impacts of replacements in particular often remain neglected.

Plastic taxes follow the same logic as levies and fees but target a wider range of products. While there is no literature on the implementation of plastic taxes across countries, the European Union, for instance, plans to implement a plastic tax on non-recycled plastic packaging waste (European Council 2020). Similar initiatives

exist in the US State of California (Simon 2020). In principle, such taxes can be raised at the counter to change consumer behavior and/or directed toward plastic producers (see Powell 2018 for in-depth discussion). The latter aims at internalizing the external costs of plastics in such that their negative environmental impacts are reflected in their pricing, in line with the idea of extended producer responsibility. Although the actual external costs of plastics are far from clear and depend on the specific context, ecosystems services approaches, valorizing the supporting, provisioning, regulating, and cultural services nature provides, can be used to estimate those. According to a recent assessment, plastic pollution results in an annual loss of $500–2500 billion in marine natural capital, or $3300–33,000 per ton plastic in the ocean (Beaumont et al. 2019).

The benefit of taxing plastic producers would be twofold. If targeting the sale or purchase of non-recycled plastic monomers or resins, a tax would incentivize recycling. If the tax revenue would be collected in a dedicated fund, this could be used to subsidize other solutions, such as innovation in materials, products and business models, or awareness campaigns. General plastic taxes could be modeled after carbon taxation following the polluter pays principle. However, the latter requires a value judgment regarding who the polluter indeed is, and different actors would certainly disagree where to place responsibility along the life cycle of plastics. An additional challenge can be that the taxes are absorbed by the supply chain and, thus, not achieve the desired aim (Powell 2018).

Apart from levies and taxes on specific products, broader plastic taxation has not been implemented so far. However, the price of virgin plastics is expected to decrease further due to the oil industry shifting their production away from fuels and massively increase their capacity to produce new plastics (Pooler 2020). Such technology lock-in will further decrease the pricing of virgin plastics, propel plastic consumption, and render solving the plastics problem uneconomic. At the same time, the surge in production may increase the public pressure and political willingness to implement taxation that mitigates the negative impacts on recycling (Lim 2019) and of increasing waste exports (Tabuchi et al. 2020) and aggregated greenhouse gas emissions (Gardiner 2019).

11.8 Solving the Societal Problem

In contrast to the techno-economic problem-solution frames discussed above, a very different perspective attributes plastic pollution to a deeper-rooted cause, namely, consumerism and capitalism. Accordingly, plastic pollution is a result of humanity's overconsumption of plastics that is, in turn, driven by our capitalist system. In this way, it becomes a societal problem. It remains unclear how pervasive such views are, but the idea that we are consuming too much is one center piece of environmentalism, arguably one of the few remaining major ideologies. The problem with this framing is that often it remains implicit in the discourse on plastic pollution. Thus, plastic becomes a proxy to debate larger, value-laden topics, such as

industrialization, economic materialism and growth, globalization, and, eventually, capitalism. The set of solutions promoted by framing plastic pollution as a societal problem are manifold. Interestingly, there is a dichotomy regarding who is responsible: When viewed as a consumption problem, solutions should motivate individuals to change their behaviors. When framed as a capitalist issue, more collective and systemic change is desired.

Plastic consumption behavior is affected by a range of factors, among others, sociodemographic variables, convenience, habits, social factors, and environmental attitudes (Heidbreder et al. 2019). The ban of plastic products, especially of single-use items, such as carrier bags, straws, cutlery, and tableware, targets the convenience and habits of consumers simply by limiting their choice. Plastic bag bans are now implemented in more than 30 countries, and bans on other single-use products are in effect in 12 countries (Schnurr et al. 2018). While generally considered effective and publicly acceptable, plastic bag bans have been criticized to disproportionally affect low-income and homeless persons. The major criticism concerns the environmental impacts of replacements made of natural materials (paper, cotton, linen) due to their higher resource demand and greenhouse gas emissions (Schnurr et al. 2018).

Social factors, including norms and identities, are the drivers for plastic avoidance, another way to reduce plastic consumption. On the one hand, social pressure and guilt can motivate individuals to not use plastics (Heidbreder et al. 2019). On the other hand, a person can practice plastic avoidance, a plastic-free lifestyle being its most intense form, to affirm their identity as environmentally conscious (Cherrier 2006). Notably, it is exactly those social norms and identities that environmental interest groups and similarly motivated actors tap into. On the business side, the marketing of "ethical" plastic products (e.g., made from ocean plastics) applies similar mechanisms, sometimes criticized as greenwashing. Interestingly, all those solutions are based on the idea of ethical consumerism, emphasizing individual responsibility, all the while staying firmly within the realm of capitalism.

As a more collective solution, activities that raise awareness regarding plastic pollution and consumption (e.g., communication campaigns) target at changing environmental attitudes and encourage pro-environmental behaviors on a wider scale. Behavior change interventions range from policies (bans, levies, see above), information campaigns, educational programs, point-of-sale interventions (e.g., asking if customers want plastic bags rather than handing them out), and the participation in cleanup activities (Heidbreder et al. 2019; Pahl et al. 2020). Importantly, Pahl et al. (2020) note that it "is advisable [to] build on personal and social norms and values, as this could lead to spillover into other pro-environmental domains and behaviours." This goes in line with the idea that awareness of plastic pollution is a gateway to wider pro-environmental attitudes (Ives 2017).

11.9 Solving the Systemic Problem

In contrast to framing plastic pollution as a waste, resource, economic, or societal problem, it can be viewed as a composite of some or all of these facets; it becomes a systemic problem. The latter view acknowledges that plastic pollution is multi-causal and that the individual causes are strongly interconnected. In other words, such systems perspective takes the wickedness of plastic pollution into account. Intuitively, this seems like the most holistic approach to the problem since it is quite apparent that plastic pollution is the result of multiple failures at multiple levels of the "plastic ecosystem."

However, the main challenge with framing this as a systemic problem is that the problem formulation becomes much less tangible compared to other perspectives. For instance, the framings as waste, resource, or economic problem are much clearer with regard to their intervention points. They also provide sets of solutions that require an engineering approach in such that technologies, processes, and functions need to be redesigned and optimized. Thus, solutions appear relatively straightforward and easy to implement. Such promises of easy wins might be one reason why the idea to engineer our way out of plastic pollution is so popular. In contrast, solutions to the systemic problem are diverse, interconnected, and at times conflicting. This makes them appear as much harder to implement. At the same time, this renders the systems view somewhat immune to criticism as individual solutions (and their limitations) will always be just a small piece of the larger approach.

Arguably, the concept of a circular economy has recently gained most momentum to tackle plastic pollution systemically. Promoted by powerful actors, including the World Economic Forum, Ellen MacArthur Foundation, McKinsey & Company, and the European Union, the vision of a circular economy is to "increase prosperity, while reducing demands on finite raw materials and minimizing negative externalities" (World Economic Forum et al. 2016). While there are multiple definitions of the meaning of circular economy (Kirchherr et al. 2017), it is basically a reincarnation of the "3Rs principle" of reduce, reuse, recycle and of the idea of sustainable design. Accordingly, a circular economy "requires innovations in the way industries produce, consumers use and policy makers legislate" (Prieto-Sandova et al. 2018). Applied to plastic pollution, the circular economy concept identifies the linear economic model as root cause of the problem.

Accordingly, it promotes designing closed loop systems that prevent plastic from becoming waste as the key solution. Whereas this seems to reiterate the solution set to the waste problem, the circular economy concept integrates the solutions supported by all other problem frames. A report by the Pew Trust and SYSTEMIQ predicts that the future plastic emissions to the ocean can only be significantly reduced with systemic change (Lau et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020). Highlighting that there is no single solution to plastic pollution, such scenario requires the concurrent and global implementation of measures to reduce production and consumption and increase the substitution with compostable materials, recycling rates, and waste collection (The Pew Charitable Trusts and

SYSTEMIQ 2020). As such, the circular approach is, thus, a composite of the waste, resource, and societal framing combined with the prospect of economic co-benefits through innovation. The latter is indeed why repacking the other solution sets in a circular economy context has become so successful that it, as an example, has been rapidly adopted by the European Union (European Commission 2018). In addition to the economic angle, the focus on technological and societal innovation provides a powerful narrative of a better future that makes the circular economy ideology even more appealing. However, two important aspects need to be considered: Firstly, it is unclear whether a circular economy is able to deliver the promised environmental benefits (Manninen et al. 2018). Secondly, we need to realize that the ideology is not as radical as it claims, given that it further promotes the current model of business-led economic growth (Clube and Tennant 2020; Hobson and Lynch 2016). Thus, more radical and utopian solutions to plastic pollution remain out of sight.

11.10 The Four Scales of Solutions

Discussing and evaluating the solutions derived from the different problem frames outlined above requires value-based judgments regarding their relative importance, desirability, costs, and social consequences. These values should be made transparent and open in the discourse on plastic pollution to mitigate the proxy politics problem. This is important because making the debate about larger value-laden issues that remain implied can result in polarization and entrenchment and, in turn, would make solving the problem much harder.

While there is a multitude of dimensions to consider when evaluating solutions to plastic pollution, there are four basic scales of change that require value judgment and social deliberation. These cover the geography, time, responsibility, and magnitude of/for change desired by different actors (Fig. 11.3).

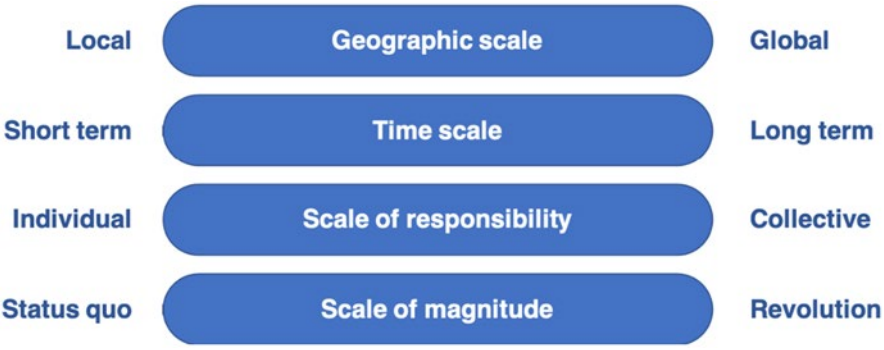

Fig. 11.3 Conceptual framework to facilitate deliberation on the scales of changes needed to solve plastic pollution

The scales of geography and time do not appear very contentious. However, the preference for local, national, regional, or global solutions to plastic pollution very much depends on which geographic unit actors most trust for developing and implementing effective measures. Some actors might be localists valuing small- over the large-scale approaches a globalist might prefer. Whereas there seems to be consensus that plastic problem is a global problem (implying a preference for global action), very focused solutions (e.g., at emission hotspots) might be very effective in a local context and much faster to implement.

The time scales desired for implementing measures and achieving their ends depends on perception of the immediacy of the problem. While a general notion of urgency to solve plastic pollution is prevailing and requires instant action, a very different standpoint may be that there is sufficient time to better understand the problem because the negative impacts are not immanent. Such view would be supported by calls for more and better research. While part of that question can be addressed scientifically, for instance, by prospective risk assessment or modeling approaches, decisions on the urgency of action remain value laden and context dependent.

At the scale of responsibility, we need to address the question who has the agency and means to implement solutions and who has to carry the burden of costs and consequences. This is as well a matter of individual vs. collective action as of which actors across the plastic life cycle have most responsibility. Some actors, especially the plastics industry, emphasize the individual consumer's responsibility. However, the systems view places much more focus on collective action. Others, especially environmental interest groups, want to hold the plastic industry accountable. However, one could also prefer to assign the burden of action to the retail or waste sectors, making it a matter of up- or downstream solutions. While it is very obvious that all actors in the plastic system share responsibility, the question of where to allocate how much accountability is open to debate.

The magnitude of desired changes is probably the most difficult aspect to agree upon because it touches not only on powerful economic interests but also on the fundamental question of whether one prefers to keep the status quo or wants to revolutionize individual lifestyles, economic sectors, or whole societies. It also covers preferences for very focused, pragmatic actions (e.g., easy wins that are sometimes tokenistic) or for systemic change. Such preferences are not only linked to perceptions of the urgency of the problem but depend on more fundamental worldviews. As with all other scales of changes, preferences will be driven by cultural context, social identity, and political orientations on the spectrum of conservative and progressive as well as libertarian and authoritarian.

11.11 How to Solve the Wicked Problem of Plastic Pollution?

Per definition, it is difficult or even impossible to solve wicked problems with conventional instruments and approaches. As argued above, plastic pollution is characterized by a relatively high degree of wickedness. At the same time, contemporary, mainstream solutions come from the standard toolbox, and it is rather the combination of all those instruments that is considered "transformative." Implementing such combinatorial approach is appealing but can be complicated by the different underlying problem formulations and sometimes conflicting value judgments regarding the relative effectiveness of individual tools.

Thus, we need to organize an inclusive, open, and probably uncomfortable conversation about the scales of change we desire and the individual values that motivate those preferences. Such debate should not be reserved for the usual actors (i.e., experts, activists, and lobbyists) but must include (marginalized) groups that are most affected by plastic pollution and carry the burden of solutions (e.g., waste pickers). The debate must be open in the sense that, for instance, instead of fighting over bans of plastic straws, we should be clear on which issues these are proxies for (e.g., consumerism). Importantly, this is not to say that we need to create an all-encompassing consensus. Instead, the current plurality in problem-solution formulations is beneficial as it acknowledges that plastic pollution is multicausal, prevents a polarization and entrenchment, and enables tackling the problem from a systems perspective.

While we will have to face a multitude of technological, governance, and societal challenges on our road to solve plastic pollution, there are some conditions that will facilitate that journey. This includes robust evidence from the natural and social sciences regarding the effectiveness of different solutions, a broad willingness to solve the problem, and an acceptance of shared responsibility.

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