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Communication of Risks and Benefits of Nanotechnology: the Issue of Societal Acceptance of Emerging Technologies

Lynn J. Frewer, Arnout R.H. Fischer, and J.(Hans)C.M. van Trijp

14.1
Introduction

The successful development, implementation, and commercialization of novel technologies is contingent on societal acceptance of these same technologies and their specific applications. New technologies associated with risks, and risks perceived by the public, have not been successfully commercialized in the past. Thus the introduction of a new technology will be contingent on being perceived to be of acceptable risk (for example, in terms of its potential impact on human health and the environment), as well as filling a need, or providing a putative benefit to the end-user, even if the benefit has not yet been recognized as important by society. Failure to deliver desirable and tangible consumer benefits would, at best, lead to public indifference to the new technology and its applications.

An individual's motivation to adopt the applications and products of the new technology would also be low under circumstances where risks are perceived to be high and benefits low. If the new technology does not align with the values and preferences of the public, public indifference might easily turn into societal rejection of the technology. Therefore public response toward the risks and benefits of new technologies should be understood, as public response may determine success or failure of the new technology. Some technologies have been described as transformative, inasmuch as their impact extends to other areas of society beyond that originally intended during their development.

Transformative technologies can be broadly defined as technologies with applications or impacts on society and the economy, which also have the potential for long-term effects on values, power structures, and ideas within society as a whole [1]. Nanotechnology, including its application to food production, and across the agri-food sector more generally, may represent such a transformative technology, inasmuch as it will result in changes to the way society organizes and regulates itself.

Technological innovations in food production have been singled out as a special case, notable because food-related issues and innovations co-evolved with human

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civilization. Human "hunter-gatherers" mastered the art of agriculture, introducing new varieties of edible crops and ways to grow and process these into safer and longer-lasting foodstuffs, thus improving food security and food quality. The rise of agricultural technology shifted the dominant societal structure from a nomadic hunter-gatherer society to one focused on stationary communities, with time available to develop more complex technologies, artistic expression, and cultural structures. As part of this, food consumption was not only integral to community survival, but also had culturally symbolic associations, and implications for employment and societal organization. Agriculture rapidly became a dominant occupation for many human beings, which further led to the evolution of agriculturally based economies. Thus the invention of agriculture can be described as transformative inasmuch as it showed the capacity to transform society by introducing completely new ways of living. What once started as simple means to control the growth of natural food sources to facilitate food security now involves application of state-of-the-art technology, involving highly mechanized tools and technological innovations for food production and food processing.

A more recent example, the "green revolution", resulted in a significant increase in agricultural productivity resulting from the introduction of high-yield varieties of grains, the use of pesticides, and improved management techniques. This enabled an increase in agricultural yields, in line with the needs of the increasing global population. An additional effect was the change in farming practices from small agrarian units to industrial-scale farming, with associated changes in the structure of rural communities and increased migration from the countryside to urban environments. The growth of cities was in turn supported by the reduced labor-intensive food production methods and the much lower risk of failed harvests, facilitated by the same "green revolution" [2].

In the context of the global market and international trade, food is treated as a commodity, and its import and export enables transactions within the global "food market". Surplus food or food scarcity determines, to a certain extent, the overall well-being of the global community. Applications of new technologies to food production may therefore be regarded as a decisive element of product and process innovation [3], and a key driver of the globalization of food production, trade, and associated food preference and culture.

Transformative technologies are not limited to the agri-food sector. In another example, developments in information and communication technology (ICT) have revolutionized not only how people communicate and deal with information, but also how they structure their working and leisure activities. At the same time, the transmission and storage of electronic information raises new issues regarding governance and privacy [4]. It is of interest to note that one aspect of ICT, the application of radiofrequency identification (RFID) technology, has now also been applied in the agri-food sector to facilitate tracking and tracing of foods and ingredients, and thus food safety and food quality. RFID technology represents an example of a technology associated with some societal concerns (for example, regarding privacy) but which has been widely accepted in the agri-food sector by various food-chain actors. At the same time, public awareness appears to be rather low, or at least reflects low levels of concern on the part of broader society.

It is likely that nanotechnology will represent an example of such a transformative technology, not only in the area of food production, food processing, and food storage, but also in other societal domains (paints, clothing, medicine, reinforced plastics for use in tennis rackets, neural enhancement, etc.). There is already discussion of the need to revise existing legislative frameworks regarding the protection of human health and the environment. In addition, the potential impact of the technology as a whole on society may be regarded as being greater than the benefits resulting from specific applications by both the scientific community and key stakeholders in industry and the policy arena.

Societal responses to emerging technological developments, particularly those which have potential to be transformative, may be ambiguous. Some technologies are accepted by society, with low levels of societal debate and controversy. Even within technologies, some applications are more readily accepted than other applications of the same technology. Most medical applications of technology are perceived by citizens to be very high in benefit, and tend to be more acceptable compared to many other applications of new technologies, even when they are simultaneously associated with risks. Exceptions seem to occur when the perceived benefits of a specific medical innovation appear to be very low for the individual receiving it, or when an individual is exposed to the medical innovation on what is perceived to be an involuntary basis – as was the case with, for example, the measles–mumps–rubella (MMR) vaccine or fluoridation of the water supply.

In the agri-food sector, public acceptance of food technologies has included, for example, the application of high-pressure processing to improve food safety and food quality, or the fortification of foods with micronutrients. In other examples of food-related technology, public negativity and consumer rejection have resulted in the failure of these technologies to deliver societal benefits, as consumers would not accept their application to foods and ingredients. Other examples of food technologies associated with public negativity can easily be identified. Food irradiation is the process of exposing food to ionizing radiation to destroy microorganisms, bacteria, viruses, or insects that might be present in the food, or to delay ripening or improve rehydration. In the 1980s, when food irradiation technology was ready for application, the technology was regarded by scientific experts as a major advance in the area of food safety and quality. However, the negative response on the part of consumers toward "irradiated" foods has resulted in low levels of uptake of food, although medical applications (for example, related to the sterilization of dressings) are widely accepted. Within the food domain, the exception appears to be irradiation of herbs and spices, possibly because public awareness of this food irradiation application is low, or perhaps because the alternative process, exposure to nitrous oxide, is viewed more negatively by consumers.

The application of technologies to food production may be particularly sensitive inasmuch as their acceptance by consumers is concerned [5, 6]. Foods (and their preparation) are associated with many traditional socio-cultural preferences and practices. In addition, global changes in food supply may be ubiquitous, and affect many consumers, particularly in a globalizing world economy where food chains (and food webs) are internationalizing. One reason why food is particularly sensitive is because food is ingested and “taken in” to the body, with the potential to influence health, and indeed one’s conception of “self”, negatively. It is perhaps not surprising that public negativity associated with the introduction of novel technologies has focused on applications in the agri-food sector, as opposed to the medical or materials sectors, as has been the case with genetically modified foods and ingredients [7]

Predicting public response regarding the application of nanotechnology to food will require timely introduction of information about end-user requirements, demands, and values into the development of new agri-food technologies. In the past, it has often been assumed that the public essentially consisted of uneducated people, who would react positively to technological innovation if they could be educated to accept the underpinning science. It is now widely recognized that public opinion, whether derived from perceptions or other non-technical concerns, is valuable, albeit representing a different perspective from that expressed by experts. The perception and opinion of different sectors of the public need to be considered as part of the policy process [8].

It is thus important to address societal and consumer preferences and demands as part of the process of technology development and implementation. In the present context, this may be particularly relevant in terms of the application of nanotechnology to food production.

14.2 Science and Society: Lessons for Nanotechnology Applied to Food Production

Food is vital for human survival, and concern about its production and preparation is widespread [9]. In this context, new technologies are increasingly being applied to ensure food security, as well as to provide additional consumer benefits related to human health and food quality. For example, limiting the health burden caused by vitamin A deficiency, particularly in developing countries, resulted in the development of “golden rice”, which has been genetically modified to increase the β-carotene content of the diet for those consumers who are deficient in this particular micronutrient. However, the problems associated with delivering the health benefits of golden rice to the populations who needed them go beyond the technological ability to develop the product.

First, there is a problem of distributing the product to consumer populations who would benefit from consuming it (the “end-of-pipe” problem). If the distribution problem could be overcome, then it is arguable that the same distribution process should be able to supply vitamin supplements, or facilitate the distribution of existing foods rich in β-carotene, as another relevant way to solve to the public health problem under consideration.

Second, consumers may be reluctant to consume the rice, which may appear discolored (yellow) compared to traditionally used variants of the same food, because of the increased β-carotene content. This increased health benefit was achieved at the cost of reduced "quality" perception.

In addition, it cannot be assumed that all consumers will accept the underpinning food technology, in this case genetic modification, even if there is a benefit associated with the end-product. Perceived benefits must outweigh perceived risks for consumer acceptance to occur. Developing an informed understanding of consumer responses to emerging technologies and their applications is key to optimizing the strategic development of science and technology in the future, as well as developing and refining commercialization strategies associated with specific products [10].

To date, societal responses to the application of different technologies in the agri-food sector has been a focus of greater societal concern compared to, for example, medical applications of the same technologies [11]. This is, in part, because many of the technologies in the agri-food sector have been developed without reference to potential consumer acceptance of different applications in the agri-food sector *per se* [3], and the situation is contextualized by an increasingly internationalized market. Although many new agri-food technologies promise to deliver profound benefits to society, they may also be associated with substantial risks in terms of both environmental and human health impacts and consumer perceptions of risk. As is the case for other transformative technologies, the impact of nanotechnology on society can be very broad and potentially unintended by the developers of the technology.

Historically, research into the determinants of public responses associated with emerging technologies (in general, and those specifically in the agri-food sector) has tended to occur subsequent to public rejection of the application of technologies. Research needs to be directed toward exploring how such products will be received before they have been developed, allowing consumer and public demands and preferences to be integrated into the design of products and technology implementation from the start.

Producers, processors, and wholesalers of food, as well as retailers, may usefully negotiate the development of new products with relevant stakeholders across regional and even cross-continental borders. Successful development of new products is ultimately dependent on society-wide consumer acceptance and purchasing of produced foods.

In parallel with developments in risk perception and communication, some authors have noted a decline in public confidence in risk analysis practices [12]. While this decline in public confidence in science underpinning technology commercialization has been evident in many technology sectors, the recent example of European negativity toward genetically modified organisms, particularly as applied to agri-food, is the example frequently cited as being of greatest relevance to societal adoption of nanotechnology, particularly in the context of its commercialization (for example, see references [13, 14]).

Despite this observation, the direct comparisons between potential societal responses to nanotechnology and other technologies may be limited. For example, nanotechnology is not as "contained" in terms of the range of potential applications as is genetic modification. The term "nanotechnology" essentially covers a broader range of sub-technologies with different applications. In addition, various combinations and convergences of emerging technologies (for example, nanotechnology, biotechnology, information and communication technology, cognitive science, and engineering in the case of human enhancement) may also raise ethical issues that include, but go beyond, those associated with genetic modification. These larger issues may influence the societal response to nanotechnology as a whole, even when specific applications in themselves do not raise such negative response.

For example, the use of nano-sieves (or nanofilters) in food processing may be acceptable in itself, but may become unacceptable in the context of widespread rejection of nanotechnology as a whole. At the same time, there is societal demand to "revisit" current risk assessment approaches, as they may not adequately address safety issues associated with nanoparticles, which may be fueled by heightened consumer risk perceptions and distrust in industry and regulatory institutions. In the absence of a clear trajectory regarding the development of public responses, it seems that companies are currently downplaying the use of nanotechnology in their products for fear of a negative consumer response and triggering distrust in nanotechnology. At this stage, it is relevant to consider how such consumer risk (and benefit) perceptions are formed, and what their consequences are in terms of consumer and citizen behaviors.

14.3
A Short Introduction to the Psychology of Risk–Benefit Perception

Much public negativity associated with the way in which risks are managed and regulated has been the result of risk managers, assessors, and other key actors in the process of risk analysis failing to take account of the actual concerns of the public when assessing, managing, and communicating information about risks. Risk assessment and management were traditionally performed without involving the public. This has (subsequently) had a negative impact on public perceptions regarding the motives of regulators, science, and industry in taking decisions or actions in relation to risk assessment priorities, resource allocation, and risk mitigation activities [15]. This may be partly the result of risk communication being implemented as a one-way transmission of the outcomes of scientific risk assessments, and the failure of responsible institutions to incorporate public concerns, values, and fears into the broader societal debate. (The interested reader should see reference [16], for example, but also Marvin *et al.* in Chapter 17 in this volume for a recently developed alternative to integrate public consultation into risk management.) Communication that is based on technical risk assessment, but does not explicitly address public concerns, is likely to have a limited role in reassuring the public. Hence it is necessary to know the actual public concerns to decide which risks should be assessed. Understanding the rationale behind public concerns thus becomes of great importance for anyone involved with new technologies.

Research into the various processes by which risk analysis practices interface with society has been evolving since the 1970s. The research of Paul Slovic and colleagues, which indicated that lay people incorporate psychological factors into their personal assessment of the acceptability of different hazards, was initially assumed to be evidence of public irrationality by different actors in the regulatory and industrial communities, and appeared to explain why risk management decisions acceptable to expert communities (for example, regulators and scientists) were not acceptable to some members of the public. The decision by some regulatory and industry stakeholders to continue to implement technologies despite negative consumer perceptions not only resulted in high levels of consumer distrust in the motives of regulators and industry, but prevented the successful commercialization of some technologies, notably in the area of genetically modified foods.

Consequently, risk communication activities at this time focused on changing public views on risk to become aligned with expert views, with emphasis on communication directed toward risk acceptance, in particular in the area of emerging technologies. The process has been described as the "deficit model" [17], whereby expert and elite organizations and institutions assumed that the various sectors of the public are in some way deficient in their understanding of risk. As a consequence, it was reasoned that the acceptance of emerging technologies and other hazards was contingent on public trust in institutions with responsibility for regulating the associated risks, rather than on the public understanding the technical assessment of the risk.

The literature suggests that public distrust resulted from the failure of these institutions to take public concerns into account. The underpinning rationale appeared to promote the notion that increased public trust in regulatory bodies with responsibility for consumer protection, industry, and science would increase technology acceptance. It was assumed that an increase in trust could be achieved by a greater emphasis on increased transparency in the process of risk analysis, in particularly risk assessment and risk management. While there is some limited evidence to suggest that increased transparency is a precondition for trust in institutional activities to develop, increased transparency in itself is not a trust-increasing event [18]. Lack of transparency may result in decreased trust, but trust *per se* is a result of citizen perceptions of institutional honesty, concern for public welfare, and competence.

A second approach to developing trust focused on greater public inclusion in the process of policy development, specifically focusing on the argument that more extensive public consultation and participation in risk management and other science and technology issues would restore public confidence in institutions with responsibility for public and consumer protection (see, for example, reference [19]). At the time of writing, increased public consultation appears to play a limited role in increasing public confidence, because there is little evidence that the output of the consultation exercise influences the policy process (see Chapter 15 in this volume, and references [20, 21]), and because there is scant evidence that institutional responses to broader consultations are able to tolerate lack of consensus in public opinion.

While there seems to be institutional and governmental motivation to conduct public consultations regarding the future of nanotechnology, it is not clear what will be done with the outputs, how lack of consensus will be handled, nor what will be the concrete ambition of the consultation. There is also some evidence that, for example, in countries with a long history of consultation, the public are suffering from "consultation overload", and the original ambition, increasing public confidence in science and technology, is more recently construed by the public as a route to technology acceptance – in other words, as a way to implement the technology regardless of public concern or demand for the technology.

More recent approaches to nanotechnology development focus on combining social science and policy research with natural science and engineering processes into "real-time technology assessment", which proposes an ongoing interaction between technology and society, permitting an iterative embedding of societal values in the emerging framework containing technology. It is argued that such an approach does not run the same risks of creating public negativity as traditional public participation exercises, which may destroy societal trust if public rejection of specific activities is not internalized into the regulatory framework [22], or block specific innovations that would be appreciated by consumers because of a societal rejection of a type of technological application at an early point in time. The effectiveness of such approaches are contingent on developing an understanding of the formation of public perceptions of nanotechnology.

14.4
How do People Form Perceptions of New Technologies

At present, there is little research regarding public perceptions of, and attitudes toward, nanotechnology. In part, this reflects low levels of public exposure to different applications under development (perhaps because of economic interests reflecting concerns about a public backlash toward different developments). Although there is a literature demanding that research into societal issues be conducted (for example, see reference [23]), in practice contemporary empirical analysis into the science and society issues of nanotechnology remains somewhat scarce.

This has parallels to research on public attitudes to biotechnology in the 1990s, where the need to understand public attitudes, and how these were forming, was identified, but research into the process was not being conducted [24]. On the one hand, there is frequent reference in the literature to the potential impact of science fiction and film/literary references to nanotechnology as being influential in terms of crystallizing public views. For example, reference is made to understand the impact of Michael Crichton's novel "Prey" as an irresponsible piece of fiction portraying nanotechnology as "out of control" and uncertain [13]. A similar discussion precluded the release of the film "Jurassic Park" (also based on a novel by Michael Crichton) and its impact on perceptions of genetic engineering. On the other hand, however, there is no evidence to suggest that public attitudes were influenced by what are clearly works of fiction (and perceived to be such). Of greater concern is the negative backlash following "overselling" of a particular technology by those scientists developing it (for example, as has been the case for human metabolomics).

At this point, it is of interest to review the existing literature on consumer attitudes to nanotechnology, with the caveat that public awareness regarding nanotechnology is not, at present, extensive [16, 25]. There is some evidence to suggest that food-related applications of nanotechnology may also result in a more negative consumer response compared to other nanotechnology applications [26]. Nevertheless, some examples of nanotechnology in foods or in food contact materials are already on the market (for example, nano-silica has long been added to non-dairy coffee creamer). Nanomaterials in food packaging are beginning to enter the market. "Smart packaging", where active components in the package control the atmosphere surrounding fresh food products, where labels respond to molecules in the atmosphere to indicate the condition of the packaged product, or where ultraviolet blockers on plastic wine bottles preserve product quality, are already possible.

Although these products may enter the market, the extent to which consumers are actually aware that nanotechnology is being applied within the agri-food sector is debatable. It is reasonable to assume that attitudes toward nanotechnology are likely to start developing in the near future, and will be formed by direct experience with the technology and its applications [27], or be driven by an affective or emotional response to the issue or application [28–30]. In the case of nanotechnology, consumers have, to date, little (conscious) experience with nanotechnology products [31], implying that information provided by external sources will probably play a dominant role in the current, early stage of public opinion formation [32].

Fischer *et al.* [33] have demonstrated that simultaneous exposure to risk and benefit information does not necessarily result in positive or negative public attitudes toward nanotechnology. After receiving balanced risk and benefit information, some individuals develop positive or negative attitudes toward nanotechnology following the provision of combined risk and benefit information. Other individuals remain neutral and do not develop strong attitudes toward nanotechnology. These results suggest that individuals develop different attitudes despite receiving the same information about nanotechnology.

Similarly, Kahan *et al.* [34] report that members of the public readily form opinions on whether the potential risks of nanotechnology outweigh its potential benefits. These are largely driven by affective or emotional responses, as well as other attitudes held by the individuals receiving the information. For example, attitudes toward environmental risks generally explain more of the differences in individuals' perceptions of nanotechnology's risks and benefits than do the other attitudes held by these individuals. The authors report that these views are amenable to influence by the provision of additional information, but that individuals exposed to balanced information polarize along cultural and political lines.

14.5 Nanotechnology Communication in the Business Context

Commercialization, aimed at the generation of willingness to buy and, potentially, willingness to pay, would require the communication of nanotechnology applications in terms of a unique benefit proposition to the consumer, primarily in terms of usefulness and ease of use [35]. In other words, what specific consumer needs are addressed by the nanotechnology application that would put it at a competitive advantage?

Cost–benefit considerations on the part of the consumer have traditionally been operationalized in terms of functional benefits of improved product performance (e.g., better taste, higher convenience, safety, etc.). However, increasingly, consumers consider not only "what the product delivers" in terms of personal benefits, but also "how the product is brought about" in terms of social and environmental impact. This is why perceived risk and uncertainty with the new technology is an essential part of the positioning challenge, as already discussed in the previous sections. Consumer behavior research [36, 37] reveals an important asymmetry, with negative societal perceptions outweighing positive contributions as a determinant of consumer acceptance. This is why consideration of public attitudes toward nanotechnology needs to be an integral part of commercial communication, particularly so, as commercial stakeholders are likely to be judged with a considerable level of skepticism and distrust.

Nanotechnology applications may occur at almost all stages of the agricultural value chain, with different potential benefits for various chain actors, all the way through from primary producers to end consumers. For effective communication of nanotechnology, it is important to identify *a priori* the business model underlying the nanotechnology application. Such a business model would include identification of "where value is being added", "to whose benefit", and "with what positioning". Following on this, the strategic management literature [38] suggests three dominant bases for realizing competitive advantage from nanotechnology applications: cost leadership, differentiation, and focus strategy. Increasingly, corporate social responsibility has come to the forefront in the business environment as a strategic orientation for competitive advantage to which nanotechnology can add considerably.

Cost leadership ("doing the same thing at lower cost") would imply that food with nanotechnology applications performs at parity with competing products (i.e., delivering existing benefit and benefit performance) in the marketplace, but that the nanotech applications add value by reducing costs anywhere along the total supply chain. This may occur, for example, through more efficient processing, and logistics with fewer losses, or more effective sourcing from increased productivity in primary production. Cost leadership approaches would not be actively communicated in terms of consumer benefit (as it delivers an established benefit), but (some of) the cost reduction may be delivered to the consumer in terms of lower price.

Nanotechnology applications also have the potential to deliver improved (e.g., step changes in taste, texture, and/or health quality of the product) or even completely new benefits to chain partners, in particular the end consumer (e.g., packaging from which freshness can be inferred). Such added consumer benefits from nanotechnology may contribute to differentiation strategies whereby the rationale for applying nanotechnology is described, together with justification for increased pricing where appropriate. Specific nanotechnology applications also have the potential for being associated with a focus strategy ("beneficial for a specific subgroup") in which the benefits brought forward by the technology would be targeted at one or two specific groups of consumers. A possible application would be the use of nanotechnology to produce a non-allergenic product, thereby opening much broader access to products for this specific segment.

Corporate social responsibility strategies, based on nanotechnology applications, would communicate the added value for society at large (e.g., in reducing environmental and social benefits) rather than the end benefits to the consumers more specifically. A key example here would be nanotechnology applications to increase the effectiveness of pesticides (and thereby reducing their use) or the development of new plant varieties that are resistant to unfavorable production conditions (such as drought and saline areas). As discussed in previous chapters, the potential for the introduction of new risks may entail the development of novel risk assessment paradigms. These also need to address consumer concerns and priorities.

Nanotechnology applications can occur at the level of process innovation and product innovation, and effective communication depends on the successful integration between the two. This is particularly important, as, in their perception and valuation of technology-based food innovations [35], consumers reply on their personal cost–benefit considerations ("what is in it for me in terms of improved product performance?") as well as risk and uncertainty, which is also largely related to process innovation ("how has this product been developed and with what consequences to whom"). For effective communication strategy, in terms of communication objectives, target audience, and message content, it is important to distinguish between different combinations of process and product innovation. This is illustrated in Table 14.1. The table distinguishes between communication strategies depending on whether the benefits arise for the chain actors (process innovation) and/or to tangible consumer benefits (product innovation).

For the net benefits delivered by the product innovation to the consumer, the end consumer is the target audience, and the marketing objective (contained in the message content) will focus on communication of those benefits to consumers and justifying the potential price premium being charged. For the benefits related to the chain actors and society at large, communication is more complicated, as, due to the complexity of the issue, the value and benefit distribution across the chain cannot easily be verified by the consumer. Consumer perception of chain

Table 14.1 A topology of societal (profit, corporate social responsibility) and consumer benefit and risk associated with different market introductions of a new technology.

Process innovation	**Products from technological innovation**		
Net benefit to chain actors	**Net benefits to end consumer**		
	Negative	**Neutral**	**Positive**
Negative			Consumer benefit at "societal cost"
Neutral			Consumer benefit at no societal cost
Positive		Societal benefits at no "consumer cost"	Synergetic quality delivery

and societal benefits are much more based on *indirect* communication through stakeholders of the value chain, most notably commercial stakeholders, non-governmental organizations, consumer organizations, media, scientists, and governments. As commercial stakeholders are not necessarily seen as an independent and trustworthy source of information, communication on chain benefits will to a large degree be delivered indirectly via these stakeholder groups. Table 14.1 highlights the importance of the aligning chain actors and social benefits of nanotechnology with actual product benefits to the consumer, as a win–win proposition between public and consumer–private interest.

14.6 Conclusion

To date, societal acceptance of new technologies has often been studied after these technologies, and their applications, have been introduced. Nanotechnology provides a unique opportunity to examine theoretical models of public opinion formation under circumstances in which consumers are only just beginning to make sense of the potential perceived risks, costs, and benefits associated with technological innovation. Consumer perceptions of risk, benefit, and cost are unlikely to be stable over time, but may have some predictable properties, which should be considered and implemented in an early stage of technology development, application, and commercialization. The success or failure of new technologies depends both on societal responses, which may create legal and governmental obstacles, and on end-user uptake, which may create or prevent the cash flow needed for further development. Careful positioning of the technology and adopting the relevant associated communication is an essential precondition to prevent adverse reactions from society.

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