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INTRODUCTION

Far-reaching scientific and technological visions are on the upswing. They promise to solve major problems such as the climate change or energy supply and to fulfil the ancient dreams of mankind such as decelerating or even eliminating the ageing process or creating artificial life. What initially sounds like earthly impressions of paradise may induce unease, concern and fear at the same time. The historical experience with regard to technology suggests to assume that ambivalences and risks cannot be avoided and that these might be bigger, the more extensive the technological interventions in nature and society will be and the more rapidly they will be made. The gap between hopes and expectations regarding progress on the one hand and concern and fears on the other hand is getting larger and larger and the waves of corresponding hope, hype and fear technologies come in rapid succession. This situation is a challenge both for social debates and for political decisions, e.g. research promotion and funding, and thus represents a topic of technology assessment – an example of topics this »TAB-Brief« is focusing on.

Scientific and technological visions are an important point of reference of the technology debate within society. In history, various forms of these visions played a significant role, e.g. for astronautics and nuclear energy – fields on which virtually utopian expectations were placed in the 1950s and 1960s. After years of disillusionment, scientific and technological visions are discussed again to an increased extent since the beginning of the century – even in the feature pages of the daily newspapers. Particularly in the field of nanotechnology (Drexler 1986), the Converging Technologies (Roco/Bainbridge 2002) and their interfaces to information technology and biotechnology as well as currently to synthetic biology, a lively communication has started about visions that are rather speculative and are reaching far into the future. Normally, *hope* and *hype* communication is soon followed by a wave of *concern* and then of *fear*.

Very often, it is a matter of one statement against another one or of positive expectation against feared risks. It is often very difficult to evaluate whether the things expected or feared in those visions have to be considered as a serious possibility or whether they are mere speculation. Now, one might say that all this is a colourful, more or less intellectual game, which – due to its highly speculative character – is only a sort of communicative background noise without real consequences. This, however, is not the case. Visions have a partly significant influence on the perception of scientific and technological lines of development, on the public assessment and opinion regarding these topics and on the form and content of social debates with regard to scientific and technological progress in general. Speculative expectations as well as fears can structure risk debates, influence research promotion and decide on the acceptance of entire areas of technology. The risk debate about nanotechnology, for example, did not start with the obvious subject of a possible toxicity of nanoparticles for human health and the environment, but with futuristic considerations whether nanotechnology could make humans redundant due to self-replicating robots (Joy 2000) – a discussion with far-reaching consequences although it is rather irrelevant in substance.

The situation of visions – both *hopes* and *fears* – being able to have a considerable factual impact though they might be merely speculative, is the core challenge for public debates, politics and thus for technology assessment. Despite all the differences of the respective areas of science and technology, this involves similar structural problems:

- *Definition problem*: Often, it is hard to evaluate what characterizes e.g. nanotechnology or synthetic biology and what is new about it. This results in debates with regard to characterization and definition combined with the skeptical question whether the respective hype technology might be just an attractive label to attract attention.
- *Technological determinism*: In the debates about hope and hype technologies, these mostly are assumed to have a deterministic intrinsic logic: It is said that the respective problems could be solved on a merely technical basis (e.g. the climate change problem could be solved by means of climate engineering) and the technologies *themselves* would result either in a catastrophe (Joy 2000) or in positive developments (more democracy due to the Internet).
- *Content of values*: Hopes and fears, packed in visions, are a complex mixture of knowledge, estimates, ignorance, values and often also interests. Thus, they are normatively loaded and express the different perspectives and conflicts of a pluralistic society. These contents of visions often are not transparent which makes it difficult to discuss the different arguments.
- *Hidden interests*: Stories about *hope* and *hype* as well as other types of futures (e.g. energy scenarios) can be used (and are used indeed) to transport interests, for example to create acceptance and to develop funding and promotion opportunities.
- *Ambivalence*: The visionary pathos in many technological visions is susceptible to the question whether things might turn out differently – and in an open society,

it is almost sure that this question will be asked. Positive visions might become horror scenarios and utopias might become dystopias. The history of nanotechnology, but also the history of the Internet, is rich in ambivalence (Grunwald 2006).

- *Inflation problem*: Hope and hype technologies focus on the new thing about them, because only like this it is possible to raise scientific, public and political awareness. As public awareness is a scarce good, there will be an inflation of scientific promises followed by the risk of an increasing lack of credibility.

This focus can only deal with some aspects of the comprehensive field. One of the great *hype* stories of the present time – with almost two decades of ups and downs already – refers to the relation of *Internet and democracy*. *Ulrich Riehm* deals with the historical roots of this relation and elaborates hopes, fears and disappointments which have characterized the co-evolution of Internet and democracy and which are still present in today's debates. *Nanotechnology* as the field which boosted scientific and technological visions to a considerable extent (Drexler 1986) will be introduced by *Christoph Revermann*. On the one hand, it fascinates due to the idea of a *homo faber* working on the molecular level who puts together atoms and molecules in a very targeted way – and on the other hand, it arouses fears in view of the possibility of self-organizing systems getting out of control. The field of *synthetic biology*, presented by *Arnold Sauter*, consequently gets on with the visions of nanotechnology in the different areas of life. Here, as it is the case for many *hype* and *hope* technologies, the definition problem is an inherent characteristic: Is synthetic biology really a new area of research or is it just a label to attract public attention and to mobilize research promotion? *Geoengineering*, a relatively new approach for a large-scale solution of the climate problem by artificially »cooling« the Earth – a topic introduced by *Claudio Caviezel* – induces fascination and horror at the same time due to the global dimension of targeted interventions in the climate system.

In order to facilitate orientation in these areas of controversial hopes, expectations, concerns and fears, transparent and comprehensible criteria as well as appropriate procedures for a consideration of arguments and decision are required. Technology assessment – also and particularly in parliaments – has the specific mission of providing a rational and transparent review of the contents of scientific and technological visions as a basis for an informed and reflected consultation of politics and society (Grunwald 2009).

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DEMOCRACY'S NEW CLOTHES – INTERNET AND POLITICS

The democratic upheaval in Tunisia and Egypt in spring 2011 once again has drawn the public's attention to the potential of the Internet with regard to democratic movements. While some considered the »Arab Spring« to be a revolution mainly supported by Facebook and Twitter, others emphasized the possibility of the ruling parties to use the Internet for surveillance, censorship and manipulation purposes. In this debate, typical patterns of a controversial debate regarding »cyberdemocracy« – which has been conducted for more than 50 years now – came to the fore. The following article deals with these discussions. First of all, it traces the technological and sociopolitical development trends which have induced the debate about digital democracy. Then, hopes and fears are presented as they appear for information, communication, participation and elections supported by information technology in a democracy. Electronic petitions of the German Bundestag serve as a current example of a specific project of e-democracy. Reconstruction shows that it is not possible to determine any cycles of the debate in which disappointments and warnings of dangers supersede (exaggerated) hopes. In fact, the typical patterns of reasoning of a debate with pros and cons are present right from the beginning.

If we try to reconstruct a debate about the significance of the Internet for politics which is conducted under the heading of cyberdemocracy, digital democracy, e-democracy, teledemocracy or similar terms, then we should recapitulate both the technological and sociopolitical developments of the past 50 years.

TECHNOLOGICAL AND SOCIOPOLITICAL DEVELOPMENTS AND PREREQUISITES

THE LONG ROAD TO THE INTERNET

The first developments regarding computer networking started in the United States in the 1950s and 1960s, mainly in a scientific context, with the research authority of the United States Department of Defense – the former Advanced Research Projects Agency (ARPA, later DARPA) – playing an essential role due to the allocation of research funds. 29th October 1969 is considered to be the day of the first remote connection of two computers, namely between the University of California (UCLA) and the Stanford Research Institute (SRI). In 1983, the TCP/IP protocol was introduced in the former ARPANET which subsequently was spread worldwide and today still represents the technical basis of the Internet. An application of the Internet which developed in the 1960s and today still dominates is the transmission of text messages (e-mail). A completely new quality of the Internet was achieved at the beginning of the 1990s with the establishment of the HTTP protocol and graphical web browsers. From most users' view, this »World Wide Web« today has become the real »Internet« which integrates numerous, totally different applications under a single interface. Another characteristic break regarding the development of the Internet was its conversion from a mainly government-funded science network to a commercial computer network: The first domain for a business company was assigned in 1985 (symbolics.com). Then, in 1995, the Internet backbone in the United States was handed over from the National Science Foundation to commercial providers (Werle 2002).

However, with the development of the Internet alone, the technical development would be described too one-dimensionally. In fact, interconnected communication networks developed thanks to the opportunities of electronic data transmission (via telephone networks) and to the emergence of home computers and PCs from the mid-1970s both in decentralized, private initiatives (e.g. the »FidoNet« mailbox system since 1984) and by commercial companies or public telephone companies. Of vital importance for the development of computer-mediated social communities has been the Electronic Information Exchange System (EIES) from 1976 on (Hiltz/Turoff 1978) or the Whole Earth 'Lectronic Link (The WELL) from 1985 on (Rheingold 1993). An example of commercially successful electronic communication services of that time in the United States is e.g. CompuServe. In Europe, online services have been developed under the auspices of public telephone companies from the 1970s on, which initially focused on a combination of remote data transmission (via telephone) and TV sets and later focused on specific terminals and the emerging home and personal computers. Whereas the »Minitel« online service was successfully established in France during the 1980s, the introduction of such systems e.g. in Great Britain (called Prestel) or in Germany (interactive videotex system called Btx) was less successful.

From the middle of the 1990s, all these systems have been ousted or superseded more or less completely by the Internet. However, these technological developments, which are independent of the Internet, are of a certain relevance, because they also incited essential discussions with regard to the significance of information and communication technologies for politics and democracy.

THE DEMOCRATIC AWAKENING SINCE THE 1960s

It is even more difficult to describe the social, sociocultural and political aspects of this development, because it is more complex and heterogeneous. In the United States, the 1950s and 1960s were characterized by a strong faith in technology and science as well as by large-scale public projects. A typical example are the American aerospace research program – from the first satellite to the landing on the moon – but also the »General Problem Solver« (GPS) developed by Herbert Simon and Allen Newell, a »program that simulates human thought« (as written in an article of 1961). The belief to be able to change society »for the better« and to make it become »more rational« by means of technology certainly is rooted here. John F. Kennedy's government program »New Frontier« gave this faith a political shape.

Completely different, but similarly shaping, was a specific American technoliberal culture of the 1960s which included both the computer developers in the legendary »garages« and the subcultural, alternative and political civil-rights, anti-war and student movements. The rebellion of students and of other groups of the population against the »establishment« also took place in Europe with its specific characteristics and called for extensive democratization. In 1969, Willy Brandt's governmental declaration took up this claim with the slogan »Let's dare more democracy« and in 1982, the political scientist Max Kaase diagnosed a »participatory revolution«. The findings regarding a crisis of democracy combined with a call for its modernization and revitalization have remained a central theme of the political, public and political science debate for decades now, so that proponents of electronic democracy could always take up the topic.

EARLY EXPERIMENTS: ELECTRONIC TOWN HALL MEETINGS AND COMPUTER DEMOCRACY

Thus, the debate about (exaggerated) hopes and fears regarding a democracy which is enhanced in terms of communication technology is not a debate only of the past few years. An early experiment in the United States of the 1970s was the above-mentioned Electronic Information Exchange System (EIES) which primarily was conceived as an information, communication and publication system for scientific communities, but for which the application regarding an »electronic direct democracy« was considered already: »The most exciting and potentially revolutionary political application of a CC system [computer conference] is the facilitation of the direct participation and voting of citizens on important state of national issues.« (Hiltz/Turoff 1978, p. 197).

Here, Hiltz/Turoff refer to Amitai Etzioni's works of the beginning of the 1970s concerning electronically communicated »town hall meetings« (Etzioni et al. 1975). For this purpose, the new possibilities of telephone conferences were used. Etzioni developed the idea of a national dialog via the pyramidal structure of small groups the delegates of which giving information to the next higher level. Telephone conferences allowed group dialogs even over long distances, in a rather short period of time and at low costs.

In Germany, Helmut Krauch propagated the idea of »computer democracy« already in 1972 (Krauch 1972). In 1958, Krauch founded the »Studiengruppe für Systemforschung« (study group for system research) in Heidelberg, which gave essential impetus for scientific policy advice as well as for the development of technology assessment in Germany (Brinckmann 2006). He criticized the lack of representation of citizens in democracy and considered the idea of computer democracy to be an opportunity of stronger participation of citizens. In 1971, a prototypical implementation of computer democracy was realized in cooperation with the WDR (West German Broadcasting). Under the direction of the well-known journalist Werner Höfer, the controversial topic of »environmental protection« was discussed within the framework of a TV show. The scientific state of knowledge with regard to currently emerging issues could be investigated by means of a computer-supported database. The viewers' opinions were taken into consideration »interactively« by means of telephone surveys.

HOPES AND FEARS

In general, it can be said that the capacities for storing, processing and transmitting data are enhanced considerably by the use of computers. Thus, more data can be stored, processed and transmitted in a shorter period of time and at lower costs. Moreover, there are three technological »M trends«: Computers are getting smaller (»micro«), increasingly mobile and are increasingly based on multimedia.

What does this mean for the hopes and fears regarding cyberdemocracy? For this, it would make sense to distinguish four functional areas which can be supported in the political process by the use of computers: information, communication, consultation/participation and decision.

INFORMATION – THE ELIXIR OF POLITICS

Democracy relies on informed citizens and politicians. The hope regarding cyberdemocracy is that a more comprehensive and better accessibility to (political) information could involve an improved functioning of democracy due to increased transparency and a higher level of information. Information is considered to be a fundamental resource for further types of political participation.

In fact, today, political information can be accessed electronically to an extent which was barely imaginable some years ago. This information is provided by political institutions themselves (governments, parliaments), but also by the media, by citizens, associations and non-governmental organizations (NGOs). Besides, »unofficial« data collections such as »WikiLeaks« have become more and more important. They by far not only consist of factual and textual information available worldwide, but also of multimedia documents such as speeches and interviews as audio, image and video files. There can be no doubt that the transparency of political processes and institutions has increased considerably. The targeted search for political information independent of place and time has been facilitated substantially.

However, in cyberdemocracy not only much more political information is available than ever before, political activities themselves permanently generate new »data traces« and the search for information and their dissemination can be traced as a matter of principle. For this reason, there was fear right from the beginning that with political information being digitalized the possibilities of citizen surveillance by the state or by large corporations would be extended considerably (Donk/Tops 1992, p. 180 f.; Hiltz/Turoff 1978, p. 486 ff.).

The hope that more political information, which can be accessed more easily by citizens, would stimulate and improve democracy is based on an understanding of politics as a rational process. The better politics are informed, the more political action can be improved, because it would be more »rational«. However, this neglects the fact that »information« in a political process is evaluated against the background of political basic concepts and interests and that different conclusions are drawn from this subsequently (Donk/Tops 1992, p. 183).

Again and again, hopes have been placed in a more immediate and direct exchange of information between politicians and citizens. Mediating entities, particularly the media with their own interests, forms of presentation and agendas, then could become dispensable. This would offer the advantage of political actors being able to transmit their information to the respective addressee in an unbiased way. However, the renunciation of such mediating entities, which reduce the complexity of information by selection and evaluation, proved to be ambivalent, if not illusory. An increase of information in the political process involves new costs regarding the search, selection and evaluation of information and there are people who cannot or who do not want to bear these costs (Schrape 2010; Zittel 2009).

COMMUNICATION WITHOUT LIMITS

The Internet offers a wide range of communication possibilities from the purely written to sound-and-image communication, from bilateral and group communication to mass communication of a »sender« to many »recipients«. Communication can take place across continents, regardless of time or as an immediate exchange of messages, in a comprehensible manner for direct participants only (i.e. in private) or in public. Typical of Internet communication – though not mandatory – is that there is no differentiation of the sender and recipient roles anymore and that intermediaries can be omitted as it is the case for mass communication transmitted by media.

Communication of politicians with their voters and citizens as well as with the public (transmitted by media) plays a very important role both regarding the self-conception and the time budget of the politicians (Riehm 2010). Hopes placed in the various possibilities of Internet communication are directed towards an intensification of this communication relationship and towards the idea that citizens can get a more direct access to politics and that they can better prepare, coordinate and communicate their own political activities in the public.

However, some politicians are afraid of not being able to cope with communicative demands due to the new variety of communication possibilities and their wide availability. The citizens' expectations regarding a dialog between citizens and politicians could be met only to a very limited extent for reasons of considerable workload. Thus, politicians focus less on a direct and equal communication relationship with the citizens than on a sender-dominated communication, e.g. in form of messages to specific lists of recipients (newsletters, mailing lists, Twitter and so on).

However, another concern is that specific and ever smaller population groups might be addressed in a very targeted way in terms of political direct marketing campaigns and thus that politics and powerful groups in society might have a considerably increasing potential for manipulation (Donk/Tops 1992, p. 181 f.). Similarly, there are fears that the Internet makes it easier for like-minded people to find each other, to organize themselves and to reinforce each other with regard to their views. This is considered to be particularly critical for democracy, if so-called »electronic tribes« (Hiltz/Turoff 1978, p. 482 f.) pursue extremist and antidemocratic objectives. In this context, a balkanization of the electorate and »demographic ghettos« have been discussed as well (Donk/Tops 1992, p. 181).

Finally, the explosion of informative and communicative possibilities involves excessive demands on society. Many people do not have the necessary resources regarding qualification and time to get involved in the »Internet community« (Grunwald et al. 2006) and there are strong indications that privileged groups of the population can benefit from cyberdemocracy to a much higher degree than the general public (already mentioned by Hiltz/Turoff 1978, p. 167 ff.).

CONSULTATION AND PARTICIPATION

Political *communication* can be initiated by very different actors with regard to various topics and is only loosely connected to political processes in the strict sense, where appropriate.

Political *consultation*, in contrast, generally is initiated by politics, focuses on a specific topic and is closely linked to political procedures. With regard to a legislative project or a political program, e.g. a ministry or parliamentary committee can invite associations, experts or citizens concerned who will answer given questions and who shall contribute their own expertise concerning the topic.

Participation procedures in a narrower sense are referred to, if there are particularly legal requirements – such as in urban and transport planning or for environmentally relevant large-scale projects – which stipulate the involvement of the people concerned in the planning and decision-making process. Generally, these procedures are based on the fact that appropriate decisions require experience and expertise from society. By taking into consideration the different views of society for the decision-making process, politics or administration shall be better enabled to balance these different interests in terms of a common welfare.

As these processes deal with the exchange of complex lines of reasoning in which more or less people are actively involved and which a broad public generally is interested in, the use of electronic group communication is an appropriate solution. This tool not only could support the current communication within the process, but also store the entire procedure and make sure that the data can be called up again at any time for subsequent evaluation. In the 1970s already, there have been experiments with such (purely text-based) computer conference systems which today can also integrate audio and video elements, of course.

Besides this information and transparency function, hopes regarding electronic consultation and participation processes are also placed in a possible opening to the broad public. As a matter of principle, anyone could participate regardless of his/her status (egalitarian tendency of the Internet), his/her resources (only one Internet access is required) and his/her location (distances do not matter anymore). Another advantage of electronic consultation and participation procedures is seen in the fact that it is possible without major effort to provide the people involved with comprehensive procedural documents and opinions for the use of which an informed participation is expected. E-consultation and e-participation as integral parts of digital democracy are already used routinely to some extent, e.g. by the European Commission (Grunwald et al. 2006, p. 87 ff.) or by the Canadian government (Lindner 2008).

Nevertheless, previous experiences have shown that the general opening of the procedures »to everyone« meets with a corresponding response under very specific conditions only and that only few people actively participate in the process (Grunwald et al. 2006, p. 15 and 21). Even more critical, however, seems to be that this type of procedure raises expectations regarding a substantial influence on political processes which in part already fail due to the fact that the opening and expansion of the »input channel« is not complemented by a corresponding expansion of processing capacities. This results in disappointment among citizens.

DECISIONS IN VOTES AND ELECTIONS

Democracy should not be understood merely as an act of electing representatives at intervals of several years or as a vote in democratic bodies. The act of voting is preceded by election campaigns and majority decision is preceded by a substantial debate. Nevertheless, elections and majority votings are something like the culmination of democratic exertion of power. By means of these processes, changes in the political course become visible, laws are set and political programs are determined.

The (supposed) simplicity of the decision-making process – normally, it is about a decision between different alternatives or a choice between different persons – suggests the use of computer assistance. In the 1980s already, there were hopes for a more efficient process and – in view of increasing electoral fatigue on the part of the citizens – for an increased voter turn-out due to automated counting procedures. As a matter of principle, votes and elections can be conducted from anywhere. For proponents of direct democratic procedures, e-voting (Beckert 2011) offers better possibilities of being able to conduct more votes with relatively little effort and thus involving more citizens in real political decisions.

»Simple« votes in terms of a determination of public moods and opinions among the population and individual groups have become more or less accepted across the board. Particularly websites of newspapers and broadcasting companies offer such »polls« almost routinely. The electronic signing of appeals and petitions is a further, rather demonstrative than decision-relevant type of »vote« even if partly formal procedural privileges could be achieved via quorums. In contrast, there are only few electronic parliamentary elections and they exist only in a few countries.

Here, it is feared that error-prone computer programs might produce wrong election results, that the anonymity of the electoral process might be endangered and that transparency of the ballot count of votes and elections might not be ensured anymore due to the »black box« characteristic of the computer. Moreover, there are warnings that the unity of debate and decision might be lost in favour of the mere act of voting. This danger was referred to as »push-button democracy« by critics already 20 years ago (Donk/Tops 1992, p. 170 and 174 f.). Today, with a similarly critical intention, it is referred to as a reduction of political activities to »clicktivism« (Karpf 2010; Shulman 2009; White 2010).

ELECTRONIC PETITIONS

In recent years, the Office of Technology Assessment at the German Bundestag (TAB) has done extensive research on the introduction and use of an electronic petition system (Riehm et al. 2009; TAB 2011). The German Bundestag provides for the possibility of petitions being submitted via the Internet and of publishing them on the e-petition platform of the German Bundestag at the request of the petitioners and following a specific authorization procedure. Further characteristics of the momentarily main e-participation project within the framework of the e-parliament strategy of the German Parliament are the possibilities of discussing petitions in an online forum and of collecting signatures supporting the respective petitions. When having reached a quorum of 50,000 co-signatures, the Petitions Committee of the German Bundestag will hold a public Committee Meeting to which the petitioners are invited in order to bring forward their concerns in person and to answer the questions of the Members of the Bundestag.

This concrete parliamentary e-democracy project also shows the typical patterns of the long-lasting debate about Internet and democracy.

The hopes of the initiators in the German Bundestag focused on a modernization of a very traditional right of political participation and on a political upgrading associated with that. The objective was to increase procedural transparency, to make the right to petition available to new groups of the population, to hear the pros and cons of a petition and, if appropriate, even to enter into a dialog with the citizens. Those hopes are shared by the citizens and petitioners who – according to surveys carried out by TAB – additionally have expected that their arguments submitted in the online forum would be considered in the petitions procedure.

However, exactly this point has been doubted by critics, because the formally weak position of the petitioners and of the Petitions Committee even with regard to the implementation of objectives which have been considered to be legitimate has remained unchanged. The fear that processing capacities cannot keep pace in case of an expansion of the »input channel« due to online forums has been confirmed by this example as well. The quite procedurally relevant contents of the discussion are integrated only unsystematically or sporadically into the procedures.

The fear that personal data are generated which might be used against the citizens is typical for the debate about e-democracy. Thus, in case of e-petitions, the names of the co-signees are accessible to anyone on the Internet. Up to now, anonymous or pseudonymous forms for co-signature are not admitted. However, there are also fears regarding the fact that the possibility of masking one's own identity on the Internet might involve misuse or that groups and organizations which are well-organized via the Internet might use the electronic petitions procedure for their political campaigns – for which it is not intended.

Unsurprisingly, the empirical studies carried out by TAB show a very differentiated picture. Altogether, the modernization of the German petitioning system by using the Internet has enhanced public awareness for this subject as well as its political significance. The citizens' intentions of using it exceed by far the capacities which the German Bundestag can provide so that many public e-petitions cannot be admitted.

For some petitions, the discussion forums show a considerably high level of participation with a generally good quality regarding the content. In fact, the use of the right to petition has been successfully extended to new groups of the population – particularly to younger people. However, the composition of the group of petitioners still clings to the typical social pattern of a kind of political participation which is characterized by a higher level of education. The fears regarding misuse by organized campaigns, by groups which are well-interconnected via online networks or by feigning false identities generally could not be confirmed.

CONCLUSION

The Internet provides an unimaginable degree of politically relevant information as well as manifold possibilities of communication and participation in democratic processes. More transparency and openness of the political system, opportunities for use which are independent of the social status as well of time and place are further typical hopes which have been expressed since the beginning of the debate about cyberdemocracy.

However, the debate also has been characterized by certain fears such as the danger of manipulation, censorship and surveillance, the social selectivity of use, excessive demands on the users in terms of information due to an elimination of mediating entities ensuring quality as well as certain opportunities for populist policy approaches.

It is impossible to determine an unambiguous cycle of *hopes*, *hypes* and *fears* over the years. Right from the beginning, there have been both hopes in favour of the topic as well as critical fears. Even the scientific and empirical analysis of the development of Internet use in democracy is characterized by this ambivalence. How can this be explained?

First of all, one reason is a one-sided technologically deterministic question: Does »the Internet« represent a benefit or rather a menace to democracy? However, the Internet is not a *hope* or *fear* technology per se, but a technology which is shaped and can be further shaped. On the one hand, the question whether rather egalitarian or hierarchical forms of communication are promoted depends on the concrete technical implementation, on the corresponding types of use and on the embedding of Internet applications in society – and not on the »Internet« itself.

On the other hand, the evaluation of specific properties of cyberdemocracy is also an issue of political basic concepts and interests. A proponent of direct democracy would consider the opportunities of e-voting rather to be a hope, whereas a proponent of representative democracy would rather consider them to be a danger. From the citizens' perspective, the possibility of directly contacting politicians and political institutions is a benefit, but for the contacted people it is often not more than just an additional burden.

After 50 years of debates about and experience with Internet and democracy, we know definitely more about the concrete conditions under which the positive potentials can be realized rather than the negative ones. Technology assessment as well – which can look back on a similarly long history – has made its contribution to this development again and again.

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NANOTECHNOLOGY: SMALL PARTS – GREAT FUTURE?

The still high expectations regarding nanotechnology are based on its potential of being able to generate material properties for completely new applications as well as to realize novel architectures and processes and to precisely adjust properties of macroscopic bodies by controlled assembly of these bodies from atomic and molecular components. For this reason, nanotechnology is expected to give new impetus for a wide range of socially relevant fields of application and innovations in almost all sectors of technology and industry. In information and communication technology (ICT), intensive work is being done on the development of new computer architectures which are intended to supersede conventional silicon electronics some day due to DNA and quantum computing. In power engineering, nanotechnology could give innovative impetus due to new materials. Novel nanoparticles could revolutionize chemical catalysis and production technologies. Finally, in medicine, nanobased therapeutics and carriers of active ingredients are being developed which can be positioned and dosed very precisely and which can escape immune defense or pass through the blood-brain barrier.

Due to its potential of fundamentally changing entire fields of technology (system innovation), nanotechnology is considered to be a key technology which might entail considerable economic, ecological and social consequences in the (near) future. Already more than one decade ago, the nanotechnology expert and Nobel laureate in Chemistry Richard E. Smalley described the consequences to be expected as follows (Smalley 1999): »The impact of nanotechnology on health, wealth, and the standard of living for people will be at least the equivalent of the combined influences of microelectronics, medical imaging, computer-aided engineering, and man-made polymers in this century.« Although this evaluation is rather speculative in part, it even then was based on the observation and analysis of tangible research and development activities.

VISIONS OF SALVATION AND HORROR

There are different visionary ideas which are significant particularly because they often dominate(d) the public awareness of nanotechnology and because they have been and still are discussed both in the feature pages and among experts. These visions are taking the next step. They are based on the idea that it will be possible in the future to manipulate matter at will and to assemble atom by atom and molecule by molecule according to one's own wishes. It is obvious that – depending on the personal point of view – this evokes either visions of salvation (»hope«) or visions of horror (»fear«). Though he often was considered to be a scientific outsider, it was first and foremost the American technology visionary K.E. Drexler with his »Foresight Institute« who initiated such discussions and who coined the term of »molecular nanotechnology« for his – predominantly optimistic – vision of the future regarding artificial, bacteria-like, self-replicating, intelligent nanomachines (»assemblers«) (Drexler 1986; Drexler/Peterson 1994). Moreover, his nanofuturistic visions prognosticated massive transformations of society and of the »conditio humana« due to nanotechnology. On the other hand, he – just like B. Joy (2000) – developed explicit horror scenarios regarding the extinction of all life e.g. due to self-replicating nanomachines which got out of control. In turn, this type of nanofuturism is part of a comprehensive and visionary ideology with regard to technology which mostly is referred to as »transhumanism« (Coenen 2010).

At the same time, these visions of Drexler, Joy and other futurists and technology visionaries are mainly based on assumptions concerning the future interactions of several new (or already known) technologies (for this, please also refer to A. Sauter's article on Synthetic Biology). Such visions of the convergence of different technologies are the drivers of hopes regarding extensive and far-reaching changes to the conditions of human existence. From this perspective, even on an administrative level, nanotechnology is considered to be an multidisciplinary element of interdisciplinary and transdisciplinary research and development and a convergence of nanotechnology with biotechnology, information technology, engineering sciences and further fields of technology is propagated under the name »Converging Technologies« (BMU 2010).

The enthusiasm which can be generated particularly by optimistic futuristic visions was used deliberately for example in the United States at the beginning of the 21st century in order to promote technology development. However, such a »hope and hype« strategy is always precarious. Besides the positive effects of this strategy (e.g. incentives for young scientists or arousing and sustaining political and commercial interest), there are also possible negative impacts: Thus, on the one hand, there is the danger that expectations of nanotechnology will be set too high, making disappointment inevitable. On the other hand, it might popularize the reverse of optimistic futurism – a pessimistic futurism involving apocalyptic fears and visions of horror. For this reason, a critical approach to these visions of horror, even if this initially makes them even more popular, would be an important contribution to a rational discussion which does justice to the problems of the potential – positive and negative – of nanotechnology (TAB 2008).

WHAT IS NANOTECHNOLOGY?

The American physicist and Nobel laureate Richard Feynman, who died in 1988, gave nanotechnology its name and therefore is considered to be its »founder«. In 1959 already, he prognosticated the technical opportunities of the nanoscale in a lecture (»There's plenty of room at the bottom«) and described the vision of assembling at the atomic level (»arrange the atoms one by one the way we want them«). Feynman (1959) assumed that there is no physical law excluding the possibility of moving individual atoms. According to that, it should be possible to manipulate matter at the atomic level. Thus, it should be possible e.g. to store the entire »Encyclopedia Britannica« on one grain of dust, if each atom would carry one bit. However, the atomic characters could be read only by means of a »super electron microscope«. This was presented 30 years later (1990) by D. Eigler and E. Schweizer of IBM Germany to the surprised press by means of an electron micrograph: 35 xenon atoms on a nickel substrate built the name »IBM« (Steinmüller 2006, p. 78).

The term »nanotechnology« itself was used for the first time in the 1970s by the Japanese researcher and engineer Norio Taniguchi. He described operating and manufacturing methods having a precision in the nanometer range. Precisely this fact – the technological control of the atomic and molecular dimension – is the actual new and particular thing about nanotechnology and offers the opportunity to optimize product properties in almost all sectors of the economy such as e.g. in power engineering, environmental engineering, information technology, in medical engineering as well as in the field of health and nutrition (VDI 2010, p. 19). Since the term »nanotechnology« was established, it has undergone changes again and again (Decker 2006). The term is mostly used for different scientific areas of research and technological lines of development which primarily have one thing in common: They are dealing with structures and processes on the nanometer scale.

First of all, »nano« – derived from the Greek word »nanos« meaning »dwarf« – refers to size. Nanotechnology deals with dimensions sized from approximately 1 to 100 nanometers (nm) with 1 nm being a billionth of a meter (1 nm = 10^{-9} m). To formulate it precisely: If a football would be shrunk to a sphere with a diameter of 1 nm, the degree of miniaturization would correspond to shrinking the globe to the size of a football. Thus, the dimension of nanotechnology ranges from the size of an atom approximately to the wavelength of visible light. Those are the dimensions in which basic biochemical and molecular-biological processes are taking place. Moreover, it marks a threshold where the behaviour of matter cannot be described only with the laws of classical physics anymore. Quantum effects occur increasingly: »Atoms stick to each other. Particles tunnel through potential barriers, which actually are impenetrable for them, and cannot be distinguished from each other anymore. Light turns around the corner and takes on a granular structure« (Steinmüller 2006, p. 77).

Thus, nanotechnology not only deals with tiny objects, but it also is characterized by using specific effects which (only) occur in these dimensions. Regardless of the reference to size, there is a tendency of subsuming a multitude of already established and new processes as a general term for a multitude of technologies dealing with structures and processes on the nanometer scale mentioned. This range will be achieved both by the use of new physical instruments and procedures via a further miniaturization of current microsystems and by the use of construction plans of animate and inanimate nature for the self-organizing assembly of matter.

RESEARCH POLICY ACTIVITIES – MUCH »HOPE«

Of course, research policy also focuses (and focused) on »nano«. A reference to the potentials of nanotechnologies is a »must« for every political statement regarding technologies of the future. Since the end of the 1980s already, research policy has increasingly adopted the term »nanotechnology«. Since that time, it was the basis of manifold research activities particularly in the United States resulting in a first climax in 1999 with the launch of the National Nanotechnology Initiative (NNI) which was announced and publicly promoted by the former President Clinton referring to Feynman's »vision« (Böl et al. 2010). Since the end of the 1990s, the development and establishment of nanotechnology as a key technology is promoted and funded by immense governmental funding programs in all high-tech regions worldwide. Every state that aims at boosting national cutting-edge research activities is intensively promoting this area of research.

In Germany, a comprehensive political program of action for nanotechnology has been formulated since the beginning of the 21st century by the government, but also by different initiatives of the German Bundestag. Among other things, this program has generated different frameworks for action and initiatives, manifold discourses, dialogs and communication platforms under participation of science, industry, government, associations and the public. Moreover, it has advanced the promotion of various projects regarding security research and provided for continuous status quo reports (TAB 2009). In order to further develop the potentials

On the international level, it has not been possible yet to find a concluding concretization of the rather diffuse »definition« of nanotechnology. Among other things, there are different opinions regarding criteria of demarcation such as e.g. the size of nano-objects and functional properties which have been modified by the miniaturization of structures, layers and objects. Germany is involved continuously in international discussions aiming at the development of a definition (EU commission, CEN, OECD, ISO) which is homogeneously manageable worldwide (German Federal Government 2010). As »interim solution«, mostly the definitions laid down by the Technical Committee 229 of the International Organization for Standardization (ISO) are quoted (BMU 2010):

- *Nano-objects*: Materials with one, two or three external dimensions in the nanoscale (approx. 1 to 100 nm). Nano-objects typically include nanoparticles, nanoplates and nanofibres, the latter comprising electrically conducting fibres (nanowires), nanotubes and solid nanorods.
- *Nanostructured materials*: These materials have an internal structure in the nanoscale and generally occur as compound systems of nano-objects (e.g. aggregates and agglomerates). In this case, however, they are not limited in their physical size or shape (according to ISO).

of nanotechnology for Germany in a strategically comprehensive way and to adapt them for use in tangible applications, the »Action Plan 2010« was implemented in the middle of the decade and it was followed by the »Action Plan Nanotechnology 2015« at the end of the decade. This Action Plan is intended to serve as a »common platform for a successful and sustainable use of nanotechnology in all its aspects« (BMBF 2010). In view of research promotion, regulation and health care, the European Union also intends to adopt a new action plan in 2011 which shall define strategies until 2015. Within the EU's 7th Framework Programme for Research alone which will be running until 2013, subsidies of much more than 1 billion Euros have been spent on nanotechnology up to now (BMBF 2010).

In Germany, nanotechnologies are funded by the public authorities with approximately 500 million Euros per year. The largest part of funds is contributed by the BMBF (Federal Ministry of Education and Research) which supports a large network of centers of excellence, e.g. for nanoanalysis, nanomaterials, nanoelectronics, nanooptics, nanobiotechnology, nanochemistry, ultrathin layers as well as molecular architectures and many others more. With a research quota of 14 % (R&D expenditure in relation to total sales), the sector of nanotechnologies currently is one of the most researchintensive technology areas in Germany. At the international level, there are signs of a neck-and-neck competition. The European Union, the United States and Japan are investing public funds of approximately 1 billion Euros each year in nanotechnologies. Adding expenditure of industry and of other important states (France, the United Kingdom, Korea, China, Russia), the total amount worldwide is likely to be considerably higher than 5 billion Euros per year (BMBF 2010; German Federal Government 2010; VDI 2010).

MARKET OPPORTUNITIES AND HOPES – MUCH »HYPE«

On the world markets, nanotechnology opens up (hopes for) new opportunities due to smaller, faster, more efficient and more intelligent system components for new products with novel or improved functionalities. There are several evaluations by market research institutes which try to quantify the »leverage effect« of nanotechnology by taking into consideration global market potentials of nano-optimized products. Due to the international interdependence of the markets, however, a regional localization is almost impossible. The sales in nanotechnology generated worldwide by companies located in Germany were estimated to be 33 billion Euros in 2007 (German Federal Government 2010, p. 12). Meanwhile, in Germany alone, almost 1,000 companies are working on the development, manufacturing and marketing of nanotechnological products and processes, approximately 80 % among them being small and mediumsized companies. More than 60,000 industry jobs depend on the use of nanotechnologies and nanomaterials (BMU 2010).

However, an exact specification of the market volume of products containing nanomaterials is impossible due to the transdisciplinary character of nanotechnology and due to the fact that it is very difficult to restrict the term »nano« to specific areas. Moreover, the corresponding »marketing departments« have long realized that the »nano« label means »hype«. Thus, the »nano« label is quickly given to all products which are provided with e.g. ultrafine or generally tiny particles and the surface of which has a sort of finer structure. Irrespective of general inaccuracies, market researchers assume that currently the market volume worldwide equals to 100 or even several 100 billion Euros with the trend of further increasing considerably (VDI 2010). Thus, already for 2015, the intersectoral market volume worldwide which can be influenced by nanotechnology is estimated to more than 1,000 billion Euros (BMBF 2010). Thus, in 2015, the market potential of nanotechnology would correspond to approximately 15 % of the industrial goods market. This would mean that a large part of the global production of goods, e.g. in the fields of chemistry, pharmaceutics, food, packaging, ICT, automotive and mechanical engineering as well as in energy and environmental engineering would be based on the application of nanotechnological know-how (VDI 2010, p. 34). However, such estimates are rather speculative, particularly because most product analyses do not evaluate only the »nano« share of the product (e.g. in case of »suntan lotion«, the full price of the bottles is taken as a basis for calculation instead of only the share of titanium dioxide nanoparticles). Furthermore, not all products labelled »nano« really contain »nano«. But even according to conservative (or traceable) estimates, nanotechnology actually shall play a role for approximately 10 % of all goods by the middle of the decade (Steinmüller 2006, p. 76).

PUBLIC AWARENESS AND RISK DISCOURSES – MORE »FEAR«

While, on the one hand, nanotechnology is praised as the key technology of the 21st century which is said to be able even to help fight the climate change, diseases and the world food problem, a closer look on it – e.g. on products being available on the market up to now – reveals a rather sobering picture: Though a multitude of everyday products enters the market, these products often have no distinct benefit or added value. Moreover, particularly the highly praised breakthroughs e.g. regarding resource conservation for manufacturing, consumption as well as for environmental technology in general are a long time coming.

At the same time, fundamental questions – e.g. that for potential risks – still remain unanswered: Nanostructures can be released into the environment, for example due to emissions in production or due to the use of respective products. Neither for shorter nor for longer periods of time, the potential consequences for humans and the environment are sufficiently known. Moreover, they have constituted a corresponding risk discourse. Indeed, politics (in Germany) focused on a distinct impact assessment as well as on a social and political support of this technology at an early stage in order to safeguard the interests of the economy and of consumers: Comprehensive research programs have been launched, new scientific institutes have been founded, common commissions of different groups of actors have been established and numerous public forums for dialog have been initiated (German Federal Government 2010, p. 12 f.). Nevertheless, it is not possible yet to make any unambiguous statements based on current scientific knowledge with regard to the question of which nanomaterials in which configuration might entail specific risks for humans and the environment. Particularly the possible inhalation of dust containing nanomaterials which is stable in a biological environment is associated with increased risks to health, because these dust particles might penetrate to the pulmonary alveoli and – in case of biological stability – might involve inflammations and chronic diseases (even cancer).

Besides the risk discourse related to health, the (necessary) discourse on nanotechnologies also includes fundamental ethical and social issues, e.g. regarding privacy and data protection aspects in view of increasingly efficient methods for sensor-based monitoring as well as of the collection, storage and transmission of medical and/or lifestyle data using nano-based products and processes. Also, bioethical aspects play a role, in particular with regard to interventions in the human organism, for individualized medicine as well as for fundamental questions on the image of humanity and on the man-machine relationship (Grunwald 2008), which could become relevant due to the application of nanotechnology. It is of decisive importance to scientifically reflect these issues and to discuss them in public in order to develop adequate solutions and to be able to present new perspectives. Here, it is important to evaluate both risk issues and ethical aspects in the context of the respective fields of application, because focusing solely on the scale of nanotechnology is not a reasonable criterion for a specific evaluation of this field of technology (BMBF 2010, p. 35).

Altogether, it can be stated that – at a relatively early stage – accompanying research in the fields of social sciences and the humanities also has been understood as an essential »partner for discourse« against the background of the development of nanotechnology as a key technology which has been recognized as such very early. Though, first of all, the focus has been on socio-economic aspects, very shortly social, ethical and legal implications in a broader sense have come to the fore as well (Coenen 2010; TAB 2008). In this process, which has been pushed not only by science, but also – particularly in the United States – by research managers and even politics, a rather traditional understanding of scientific and risk communication (initially) prevailed. Here, first of all, the objective was to inform people about nanotechnologies focusing on the opportunities they offer (Böl et al. 2010, p. 14). As a counterpart particularly of nanofuturistic visions (of horror) (e.g. Joy 2000), namely the far-reaching expectations of possible opportunities were used in the communication with the public in many cases and very intensively through transmission by the media. This, in turn, was discussed in the media and in the public immediately and very critically. At the same time, another aspect of the nanotechnology discourse was the concern whether strongly exaggerated expectations might arise with regard to nanotechnology and necessarily might be followed by disappointments e.g. against the background of extremely far-reaching (positive) visions (i.a. Roco/Bainbridge 2002), which had been developed in a strategy of »hype and hope« particularly in the United States (Paschen et al. 2004).

As things developed, it became obvious that the political and scientific discussions on nanotechnology mainly focused on the concern that the public or finally the consumers could respond to the newly implemented key technology with similar fears concerning risks and thus with rejection as it already was the case with some subareas of biotechnology and genetic engineering (e.g. green genetic engineering, cloning). Thus, there was the concern – e.g. due to repeated and insistent warnings by some non-governmental organizations, mainly by the ETC (2006) – »that with regard to the perception of risk, imaginable impacts on health and the environment might entail a general rejection of nanotechnology« (Böl et al. 2010, p. 15). It could be illustrated by several studies that such a concern was not generally unfounded and that, for this reason, a transparent and differentiating discussion and provision of information regarding nanotechnology and the resulting specific production processes, products and applications is required (Fleischer et al. 2010).

Particularly against the background of nanomaterials being increasingly used in consumer-near products and of an increasing and stronger exposition of employees, consumers and the environment becoming probable, consumers meanwhile are evaluating the fields of application in a very differentiated way and are calling for an explicit labelling. In particular in view of a distribution of nanotechnology-based everyday products such as cosmetics, cleaning agents, clothes and household articles, the aspects of food safety and consumer protection are becoming more and more significant (Fleischer/Quendt 2007). However, in Germany and also in Europe, information about the use of nanomaterials in products is not (uniformly) regulated by law, but to date mostly depends on the decision of the product manufacturer. Thus, in Europe, e.g. the labelling of nanoscale components in cosmetics will be mandatory only as of 2013 (BMBF 2010, p. 29). Nevertheless, particularly the areas of food and health are considered to be those fields of application which are most likely to be hit by controversies. Moreover, it has to be assumed that the way the relevant actors are dealing with consumers' needs for information and safety will significantly influence the attitudes and perceptions of the consumers (Böl et al. 2010; Sigrist et al. 2007). In Germany, Great Britain and in Switzerland, this could be identified within the framework of several public dialog procedures and consumer conferences. According to Möller et al. (2009, p. 110), the following relevant demands made by consumers can be stated in detail:

- labelling in order to allow an informed choice of products and to avoid that consumers are misled with regard to products;
- active information policy concerning research projects and initiation of public debates;
- more comprehensive risk research, risk prevention and corresponding measures of risk management;
- authorization procedures for nanoscale substances in food or additional assessment of already authorized substances in case they are nanoscale.

In general, the interactions as well as the contrast of expectations and the real perception of benefits are obvious. Finally, it is exactly this interaction which can strongly influence the (further) line of development and implementation of a field of technology. »Consumer decisions can represent the critical corrective with regard to exaggerated expectations. At the same time, exaggerated expectations might make consumers suspicious of an entire research area and consequently might prevent investors from contributing to its further development.« (Böl et al. 2010, p. 15).

INNOVATION CULTURE – PRAGMATIC MANAGEMENT OF RISKS AND OPPORTUNITIES

As surveys show, in the middle of the past decade, the majority of the European citizens initially considered nanotechnologies as generally beneficial to society and not as particularly risky. Correspondingly, according to Eurobarometer surveys, the majority was in favour of promoting nanotechnologies (Gaskell et al. 2006). Recent empirical studies on risk perception regarding nanotechnology make the concern of a general rejection of nanotechnology by the population appear rather unfounded as well. The result of a representative survey of the population concerning risk perception (Zimmer et al. 2008) was that two thirds of the respondents expect nanotechnology to offer more benefits than risks and that there are positive expectations particularly with regard to medical applications. However, it has to be taken into consideration here that many respondents comment on opportunities and risks of nanotechnology though many studies from numerous countries reveal that they have only little or even no knowledge at all regarding this technology (von Rosenbladt et al. 2007; Siegrist et al. 2007). At the same time – just as it has been shown – in many cases there was a lack of specific knowledge concerning the risks of nanotechnology in production and application and many governments and authorities in charge arranged to think more intensively than before not only about possible consequences of using this technology, but also to envisage tangible measures for regulation and prevention.

It is unquestionable that – with regard to managing these issues – a responsible assessment of the risks and opportunities involved is required for both individuals and society as a whole and that corresponding discourses have to be conducted in a transparent, public and continuous way. Besides such debates – which refer to concrete aspects of nanomaterials and nanoproducts as well as to possible consequences for humans and the environment – several activities and discussions can be identified in the context of discourses and accompanying forums of cultural, political and social sciences as well as of the humanities which, for example, are dealing with the question of which possibilities exist in society to develop and to implement an »innovation culture« in a field of technology such as nanotechnologies (Kahan et al. 2009). Such an innovation culture includes e.g. discursive development and establishment of general concepts which are committed to the principles of sustainability and/or socio-ecological prevention. Correspondingly, the necessary and politically desirable intention would be to achieve a reasonable degree of »orientation« as well as a »reduced complexity« of the technology field with regard to society's perception. In terms of a »dialogical development of a general concept«, this might contribute to reducing uncertainties regarding possible opportunities, risks, successes and failures in the development and application of innovative key technologies, to removing unnecessary obstacles to an establishment of the technology or to prevent an inadequate »hype« as well as an exaggerated »technology push« resulting from that.

Finally, it is about a changed understanding of the role (e.g. and also of cultural aspects) of science (or its methods used for gaining knowledge) in society and a stronger integration of this (new) understanding in politics. From the perspective of a participatory approach for discourse, the »evaluations of lay people based on real-life would no longer have to be considered as an expression of lacks of knowledge to overcome« and »the driving forces of scientific and technical progress would have to be analyzed thoroughly and by abandoning traditional conceptualizations« (Böl et al. 2010, p. 14). In recent years, these opinions or findings have developed increasingly in Europe as well – following the example of the United States. Correspondingly, this has been reflected in the public's perception of nanotechnology and in the discussions with regard to its public perception. Here, it has become apparent, among other things, that the cultural, political and ideological attitudes of the (respective) population essentially co-determine the perception of risks and opportunities as well as the – even political – evaluation of nanotechnology (Currall 2009; Fleischer et al. 2010; Kahan et al. 2009).

In contrast to the United States (and partly to other European countries) where nanotechnology was and still is politically communicated within a rather technophile framework (TAB 2008), the German policy approach represented by the German Federal Government's »Nano Kommission« is focusing on the precautionary principle as well as on sustainability and environmental aspects (BMU 2010) – aspects which have been of particular importance in society and politics for quite some time now. Thus, largely shared cultural and political influences are followed up – without neglecting the issue of innovation (Grunwald 2008). Altogether, this corresponds to a constructive approach for discourse with the objective of giving a »hope, hype and fear technology« a sustainable and generally acceptable direction of development.

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SYNTHETIC BIOLOGY: FINAL TECHNOLOGISATION OF LIFE – OR NO NEWS AT ALL?

Synthetic biology currently represents a prime example of a »hope, hype and fear technology«. On the one hand, it has a close methodological connection with genetic engineering while, on the other hand, being close to nanotechnology and converging technologies in discursive terms. Even though there is as yet no consensus about the essence and prospects of synthetic biology, it is regarded by many as the key direction in which developments are heading in biosciences – with the latter being seen in turn as the defining science of the 21st century, following in the footsteps of physics in the 19th century and chemistry in the 20th. This paper will show that a certain discrepancy can be identified between the extent of the expectations, hopes and fears under discussion and the available fund of knowledge or of specifically foreseeable potential applications.

One characteristic feature of hope, hype and fear technologies, without doubt, is that every debate about it is preceded by a discussion of its definition or whether there is a common understanding of what it means. Although this seems absolutely inevitable with a new technology or a new branch of science, the question about definitions and understanding has a different meaning in the three examples of nanotechnology (central theme of paper by C. Revermann), converging technologies (TAB 2008) and synthetic biology: that is because the question is whether the current status of knowledge, data and technology allows a new, discrete field to be assumed – or whether this is just a relabelling of incremental progress or a new name for something long familiar.

IN SEARCH OF A COMMON UNDERSTANDING

Almost every paper which addresses the prospects, opportunities and risks of synthetic biology reflects and comments on what differentiates it from a mere further development of genetic engineering – which for its part can be very well demarcated because the targeted modification of naturally occurring DNA can be defined as the intersection of all genetic engineering applications.

The understanding which forms the basis for the current TAB project on synthetic biology has been defined as follows (http://www.tab-beim-bundestag.de/en/research/u9800.html): »Synthetic biology is the designation for a field at the interface of biology, chemistry, biotechnology, engineering science, and information technology. It is based on findings and methods from molecular and systems biology, in particular the decoding of entire genomes and the technological advances in the synthesis and analysis of nucleic acids. The idea underlying synthetic biology is the creation of new biological systems that do not occur as such in nature and the design of individual molecules, cells and organisms that exhibit new properties with the aid of procedures from molecular biology and standardised principles and methods from engineering science. In doing this, different strategies are being followed:

- Mechanical, synthetic production and sequencing of DNA
- Synthesis of protocells with the properties of living cells with the aid of biochemical substances lacking a concrete biological model
- Construction of minimal cells with synthetically produced genomes
- Integration of artificial biochemical systems in living organisms to achieve new properties
- Construction of chemical systems (new biomolecules) corresponding to biological models such that these systems manifest certain properties of living organisms
- Reduction of organisms to rudimentary system components by installing standardised modular biological parts (›BioBricks‹) for the purpose of creating biological circuits that respond to external stimuli«

This description deliberately avoids an advance positioning on the news value of synthetic biology and serves as a starting point so that, as a result of the systematic capture of application potentials and risks, it is even possible to discuss whether the term and content are really forward-looking and relevant, i.e. whether there is even a cause for hope and fear.

The antipole to such a position which is initially about searching is formed by those who understand or postulate the creation of »artificial life« as the core goal of synthetic biology and place it at the centre of the debate. This almost inevitably gives rise to the question of the legitimacy of »playing God« as a metaphor for the philosophical and theological discussion of necessary and desirable limits on human action when interacting with nature. »Synthetic biology shifts human interaction with nature from the paradigm of manipulation to that of creation,« write, for example, Boldt et al. (2009, p. 80); »Vom Veränderer zum Schöpfer« (From modifier to creator) is the title of a paper by the Director of the TAB (Grunwald 2010a). Similar formulations have been used since the emergence of genetic engineering in the 1970s for almost every important biomedical development (prenatal and pre-implantation diagnosis, cloning, stem cell use), and they reliably generated public attention, though this is mainly characterised by fear and less by hope (see below).

And how could hype arise? Where can these exaggerated hopes come from? The easiest way to explain these is to select a third perspective on the issue of synthetic biology, i.e. the assumption of the systematic and synergistic merging of biomedical and engineering developments in what are termed converging technologies (Coenen et al. 2009; TAB 2008). »Biology is becoming technology« and »Technology is becoming biology« – according to the »Making Perfect Life« project of the European Technology Assessment Group these are two megatrends which will shape our technical and economic future (ETAG 2010). Based on this assessment there is a clear assumption that synthetic biology is positively predestined to be *the* key technology for resolving mankind's future problems because it unites all the major technologies.

Overall it may be assumed, both in the case of synthetic biology and also for other technological developments, that the extent of hope, hype and fear is greatly influenced by the chosen perspective and the resulting preoccupation with the potentials. The considerations outlined below are intended to substantiate three assumptions relating to synthetic biology:

- To date there have been – surprisingly – few hopes in the sense of target applications, or they have been far from specific.
- Exaggerations mainly accompany the topos of the creation of artificial life – and have less impact than might be expected.
- For various reasons the fears that could be mobilised have been contained to date within comparatively tight limits.

HOPE: IMPROVED MICROBES AND DIVERSE ACQUISITION OF KNOWLEDGE

The same applications for synthetic biology are repeatedly cited as the future prospect (e.g. in the overview studies on the potentials of synthetic biology in box 2): bioenergy and raw materials production with optimised or »newly designed« microorganisms, biosensors for environmental monitoring and medical diagnostics and various strategies for the manufacture of pharmaceuticals and new therapy and vaccine variants.

However, a precise analysis of the applications concretely pursued and developed a little further to date, such as took place at a workshop of the Engineering Life project (www.engineeringlife.de) (König et al. 2011) which is sponsored by the BMBF (Germany's Federal Ministry of Education and Research) reveals that practically no or scarcely any example can be identified which cannot be regarded as a mere further development of molecular biological and genetic engineering methods which have been in use for some time – or vice versa that qualitatively delimitable approaches, such as the comprehensive »construction« and »implementation« of new metabolic pathways in bacteria or yeasts or even the complete *de novo* design of microorganisms, currently still constitute basic research without any certainty of technical feasibility and utility.

With reference to synthetic biology, therefore, it is particularly relevant to ask whether the current status of research is really such that it is possible to talk of a new development stage in applied biosciences or even a paradigm shift. Many scientists regard synthetic biology to date more as an almost playful, experimental use of new technical options without any fundamental strategic importance – along the lines of the International Genetically Engineered Machine competition, iGEM (http://ung.igem.org), set up by Massachusetts Institute of Technology (MIT) and run annually since 2003 in which groups of students vie for the most original and forward-looking projects using BioBricks. Perhaps the greatest consensus among scientists working in this field could be that the methods brought together under the synthetic biology label constitute a gain in knowledge in basic research, particularly with reference to the functioning of genes and genomes but also of other molecules and cell components without direct applications having necessarily to result from them.

HYPE: »LEBEN 3.0« AND – YET AGAIN – SAVING THE WORLD

Hype – i.e. an exaggerated expectation of the future potential – can only accompany spectacular scientific successes which are easily communicable to the wider community in the case of synthetic biology to a limited extent. The primary opportunity for dramatisation is the image of the artificial production of life in the laboratory – which, even though it can hardly withstand serious scrutiny, has a centuries-old tradition to call on. It is no surprise on the one hand, therefore, that a clear interest has developed in the humanities and arts for an interdisciplinary debate on the potential significance of synthetic biology (e.g. the proceedings of the »Leben 3.0 and die Zukunft der Evolution« [Life 3.0 and the Future of Evolution] conference of the Berlin-Brandenburg Academy of Sciences and Humanities in cooperation with the Berlin Medical Historical Museum of the Charité University Hospital on

16/17 September 2010; Gerhardt et al. 2011) and, on the other hand, that the visual arts are addressing the issue, especially through the medium of the cinema (such as in May of this year in Vienna at Bio:Fiction, the world's first film festival devoted to this theme; www.bio-fiction.com).

Some scientists are presenting the complete synthesis of genomes, i.e. the central genetic information of a cell or organism, as the current variant of creating life. Following the successful sequencing of the genomes of three viruses – including the reconstructed virus of the Spanish flu of 1918 – by 2005, scientists from the laboratories of Craig Venter, probably the greatest media star among genome researchers, reported the complete synthesis of a bacterium genome which is many times greater (see Schummer 2011 in relation to this and the following). The to date greatest public sensation was generated by a press release from the J. Craig Venter Institute in May 2010 which stated that scientists had created the first synthetic, self-reproducing bacterium cell. As Joachim Schummer emphasises in his book »The Craft of Gods: The Artificial Creation of Life in the Laboratory«, the press release contains an unusually detailed exposition of the scientific methodology which, in conjunction with a superficial reading of the related scientific paper, would have made clear that this is nothing to do with a *de novo* creation of life in the laboratory, but merely a further step in the use of large DNA molecules and a targeted manipulation of bacterium cells. At the same time, however, the message of the »synthetic genome« and the »synthetic cell« was declared so prominently and further hyped in interviews that artificial life was the media message that emerged after all (Schummer 2011, p. 113 ff.). This also occurs as a result of people equating »synthetic cell« with »artificial cell« (i.e. without a natural paradigm) in everyday speech. Interestingly, the religious implication in the sense of »playing God« occurred almost only in Catholic- and Hindu-dominated countries or media (including a large part of the German press), whereas Protestant, Islamic and Jewish voices tended more towards the »Frankenstein« or »Pandora's Box« image as a warning against possible uncontrollable dangers (Schummer 2011, p. 119 ff.).

All these images give rise more easily to scary (see below) messages about alleged artificial life than hopeful ones – the latter requires a connection with humanity's great challenges: world food affairs, global health, global energy and raw materials demand or resolving global environmental problems. However, it seems that the current status of synthetic biology does not really allow these positive hype goals or visions to be underpinned. One probable reason for this is that practically all of those involved emphasise that only microorganisms will be manipulated for the foreseeable future. In medicine this results in possible application prospects for simpler and more efficient production of complicated pharmaceutical molecules or for the optimisation of gene therapy processes using better vectors, i.e. vehicles for introducing the therapeutic DNA or RNA molecules. Neither of these is a revolutionary new approach, which therefore means that projections relating to synthetic biology do not offer any completely new prospects in medicine.

A »hype message« is most easily associated with renewable raw materials and fuel production with the aid of algae and other protozoa »designed« *de novo*. The primary goal which can be defined here is to resolve the food vs. fuel problem with regard to the use of agricultural land and the protection of natural ecosystems (e.g. World Economic Forum 2010). This problem and its repercussions on food prices and the world food situation have become a central political and social point of contention with reference to the use of scientific and/or technical options. If visions of synthetic biology could render plausible a means of producing raw materials and fuels which saves land and resources, this would represent an ideal trigger for hype.

However, the communication of this vision has yet to really gain momentum. One reason could be that the debate on the global demand for energy and raw materials has become extremely complex, differentiated and controversial in recent years – completely independently of the developments in synthetic biology (SRU 2007; TAB 2010; WBGU 2009). It is difficult, therefore, for simplified proposed solutions and left-field visions to have an impact, in scientifically and politically relevant circles at least, but also in serious media. If genuine hype is to be generated here, it would have to be possible to report substantive results, e.g. relating to an increase in efficiency from the use of synthetic biology – but this is apparently not the case to date.

Because of their experience with the hope, hype and fear technology cycles up till now, secondary research and government funding bodies now react, depending on their point of view, as if this is all quite normal or with almost slightly hasty submissiveness. The natural sciences underpinning technology are scarcely able to meet the relevant demands with reference to producing new knowledge and developments. This results in the same old examples and considerations being brought up again and again, a reflex action which hardly any relevant institution is able to elude.

So, where is the hype in synthetic biology? Or does it not actually exist, and is it all just measured hopes without any exaggeration? The large number of projects, reports and statements actually indicates that it must exist. One possible suspicion is that the hype surrounding synthetic biology is something that happens in the »observer community« (from the field of technology assessment and innovation analysis, philosophy of technology and bioethics, in other political consultancy and research funding bodies) – as it were in the »discursive superstructure« of synthetic biology.

FEAR: MONSTER GERMS FROM THE GARAGE AND OTHER GHOULS

Particular fears can be caused especially if something is entirely new or unknown, if it has the potential to cause significant damage or if people feel they may be especially affected by it.

Because of the lack of fundamental difference from previous developments in molecular biology and related research and applied fields, no concrete risk scenarios are actually emerging, given the current development status of synthetic biology. All the restrained statements on synthetic biology are in agreement here. At the same time they mostly also point out that this could change in the event of possible major development strides and that close, ongoing monitoring and analysis are therefore needed (please see in this regard the studies on the potentials of synthetic biology in box 2).

Such a step would be the »construction« of massively modified microorganisms, especially if they were to be used in the environment, outside of bioreactors. Such releases have not yet taken place, and many scientists regard this as unjustifiable. A recurrent idea is the thought of using synthetic biology methods to incorporate mechanisms in the future microbe creations which will prevent uncontrolled reproduction, e.g. by using molecules which do not occur in nature as a kind of »genetic firewall« (Marlière et al. 2011; Schmidt 2010).

However, more concrete fears are directed not only towards the targeted, monitored use of organisms or substances manufactured by means of synthetic biology, but also towards those produced by amateurs in garage laboratories, whether intentionally or simply accidentally. This would be the other side of the coin from the playful/creative attempts by academics and researchers – if a relevant number of people were actually to start using BioBricks for fun or to scare others. It is generally agreed that genetic engineering can now be carried out with comparatively little expertise and relatively inexpensive equipment. What is unclear, however, is how many »DNA DIYers« are already at work. However, the self-regulation within the associations of companies which are contracted by customers to produce large DNA molecules commercially as a raw material demonstrates that this danger is not regarded as irrelevant. In this the member companies undertake to check DNA orders for possible sequences of pathogens or toxins and also to document the orders and report suspicious orders to the authorities (IASB 2009).

On the other hand, attempts to impute an even greater danger to biodiversity

BOX 1: SELECTED EUROPEAN AND GERMAN TA STUDIES AND INNOVATION ANALYSES IN SYNTHETIC BIOLOGY

- »TESSY – Towards a European Strategy for Synthetic Biology« (Fraunhofer ISI, Karlsruhe; on behalf of the EU Commission; concluded 2009): analysis of the issue from the perspective of research and innovation strategies
- »SYNBIOSAFE: Safety and ethical aspects of synthetic biology« (ITA and IDC Vienna, University of Zurich, ISTHMUS SARL Paris; on behalf of the EU Commission; concluded 2009): analysis of safety-related and ethical aspects and the public debate on the issue
- »SYNTH-ETHICS« (Technical University of Delft, Dutch research institute TNO, the University of Padua, the Australian National University and ITAS, Karlsruhe; on behalf of the EU Commission; concluded 2011): analysis of ethical, legal and social implications
- »Making Perfect Life« (members of the European Technology Assessment Group: Rathenau Institute, The Hague, Fraunhofer ISI, Karlsruhe, ITA, Vienna, ITAS, Karlsruhe; on behalf of STOA, the TA panel of the European Parliament): Synthetic biology (»Engineering of Living Artefacts«) is one of four sub-themes (in addition to »Engineering of the Body, of the Brain and of Intelligent Artefacts«)
- »Engineering Life« (Institute for Ethics and History in Medicine and Centre for Biological Signalling Studies (BIOSS) at the University of Freiburg; ITAS, Karlsruhe; Theological Faculty of the University of Erlangen-Nuremberg; funded by the BMBF; start 2010): reflection on the ethical/philosophical and theological relevance of synthetic biology; analysis of the potential applications and statutory framework for dealing with potential threats
- »SynBioTA – innovation and technology assessment of synthetic biology« (University of Bremen; funded by the BMBF; start 2010): comprehensive analysis of potential with reference to future focuses of research policy

or the biosphere as a whole from the visions of synthetic biology than is represented by »classic« gene technology and generate public debate have remained astonishingly low-key. It may be assumed that the declared opponents are also finding it difficult to communicate a plausible definition and vision of synthetic biology which could be even scarier than the applications and objectives hitherto for genetic engineering. The warning against selling off nature and against the unforeseeable consequences for the environment and health and the scares about the world view and the (patenting) intentions of scientists, industry and government were intensive enough with (green) gene technology and cannot be convincingly further intensified by adding the attribute »extreme« (»extreme genetic engineering« was the label applied to synthetic biology for a time by the ETC Group; ETC 2008).

The attempt to postulate a new form of protection, »evolutionary integrity«, and to introduce it into the debate about the protection of biodiversity, as in the case of the German non-governmental organisation »Testbiotech«, which is critical of gene technology (Then/Hamberger 2010), is a more interesting concept. However, it is not yet possible to say whether this will fall on good soil and will perhaps be able to move the scientific debate forwards.

In addition to these worries about the intended (»biosecurity«) and unintended (»biosafety«) consequences for the environment and health, the ethical and theological concerns about mankind's possible arrogance in shaping nature improperly to fit his own desires must be seen as part of the fears and anxieties about synthetic biology. Here, too, however, there are two factors which mean that, given the current state of synthetic biology, the warnings against playing God will ultimately have little effect: firstly, because, for the foreseeable future according to practically all scientists, the issue primarily involves microorganisms which are to be modified and shaped for human purposes, and secondly, because – as with the concerns about biosecurity and biosafety – horror stories have always been circulated warning of eventual overstepping of limits, such as the breeding of humans, in connection with much more advanced or even established technologies (preimplantation diagnosis, stem cell research, cloning, germline therapy). If synthetic biology is to cause specific and new fears, it would need more plausible scenarios than hitherto which would presumably have to refer at least to higher plants or animals.

GOVERNMENT STRATEGIES: PROMOTING RESEARCH AND DIALOGUE

The systematic monitoring of new scientific and technical developments with possible social, especially socio-economic relevance has been practised by all major industrial countries for years. The EU Commission addressed synthetic biology as long ago as December 2003 under New and Emerging Science and Technology (NEST) and announced a project tender in the autumn of 2005 with a value of 50 million euros. The major part of this went on scientific research projects, but a range of projects relating to the ethical, legal and social analysis and technology assessment (TA) of synthetic biology were also commissioned (box 1). In recent years reports and statements have been published by various bodies and institutes which advise governments, including in the Netherlands, the UK, Switzerland, Germany and the US (box 2).

A rigorous comparison of these documents in terms of relevant differences is beyond the scope of this paper, though a few striking areas of commonality may be mentioned:

- None of the reports exaggerates the opportunities or risks of synthetic biology, which is not surprising in light of the constantly more comprehensive, deliberative approach, but is due to the early and as yet unclear development stage as described of most synthetic biology projects.
- Nevertheless, synthetic biology is judged to be an important development field with major potential that should be promoted systematically and comprehensively.
- All the statements from European countries and the EU at least clearly declare that a very important intention is to address the possible risks intensively from the outset, for precautionary reasons, on the one hand, and in order, on the other hand, to prevent a resulting debate in society blocking the use of potential opportunities.
- The key recommendations on action resulting from this are the consistent continued monitoring of the scientific and technical field, including a regular review of whether national and transnational funding and regulatory measures appear appropriate, together with a comprehensive social dialogue on the opportunities and risks and how to deal with them. The guiding principle is good governance in the sense of planned action by responsible government, scientific and business representatives.

It is clear that the analyses and assessments of synthetic biology are shaped by earlier experience with the associated technology fields – emerging or new technologies, technical sciences or whatever you wish to call them – of

BOX 2: SELECTED REPORTS AND STATEMENTS ON THE POTENTIALS OF SYNTHETIC BIOLOGY

- *Netherlands*: Commission on Genetic Modification (COGEM) (2008): Biological machines? Anticipating developments in synthetic biology.
- *Germany*: Deutsche Forschungsgemeinschaft (DFG), Deutsche Akademie der Technikwissenschaften (acatech), Deutsche Akademie der Naturforscher Leopoldina (2009): Synthetische Biologie – Stellungnahme.
- *United Kingdom*: The Royal Academy of Engineering (ed.) (2009): Synthetic Biology: Scope, Applications and Implications. The Royal Academy of Engineering (ed.) (2009): Synthetic Biology: public dialogue on synthetic biology. Biotechnology and Biological Sciences Research Council (BBSRC), Engineering and Physical Sciences Research Council (EPSRC), Sciencewise – ERC (2010): Synthetic Biology Dialogue.
- *Switzerland*: Schweizerische Eidgenössische Ethikkommission für die Biotechnologie im Ausserhumanbereich (EKAH) (2010): Synthetische Biologie – Ethische Überlegungen.
- *EU*: European Group on Ethics in Science and New Technologies (EGE) (ed.) (2009): Ethics of synthetic biology.
- *Member States of the EU*: The European Academies Science Advisory Council (EASAC) (2011): Realising European potential in synthetic biology: scientific opportunities and good governance.
- *USA*: Presidential Commission for the Study of Bioethical Issues (2010): New Directions. The Ethics of Synthetic Biology and Emerging Technologies.

gene technology and nanotechnology. Following the largely hostile political and social response to green gene technology – in particular the planting of transgenic crops – in Europe in the 1990s which was seen, at least by its proponents, as a disastrous failure and was blamed by many observers on poor communication, nanotechnology in the first decade of the new millennium offered an example of a significantly more complex, varied and assured discourse (as made clear in the paper by C. Revermann in this section).

In synthetic biology it is almost possible to gain the impression that the debate about opportunities and risks, while not in principle coming too soon, is nonetheless slightly too feverish. The fundamental uncertainty stated at the outset as to whether this is a meaningfully discrete field of science and technology leads to major problems of understanding, particularly with the general public, in association with the far from clear application prospects in the attempted public debate to date. In the case of synthetic biology, scientists and politicians are evidently especially susceptible to the Collingridge dilemma, with which TA and forward-looking technology design are fundamentally faced (Collingridge 1980; Grunwald 2010b): If you don't want to be too late, you'll have to find your way in the dark.

For the German situation an evident but surprising feature should be noted when dealing with the problem of definition and understanding related to synthetic biology: while important professional associations and special interest groups within the German scientific community, especially the Leopoldina and acatech national academies, started to work extensively on the issue of synthetic biology as early as 2008 (box 2) and the Bundestag, as a consequence of initial soundings in its parliamentary Ethics Committee, commissioned the TAB with its current project, the relevant ministry, although also commissioning two TA projects (box 1), has otherwise consistently avoided using the term »synthetic biology« in its funding programmes. This becomes particularly clear in the Biotechnology 2020+ strategy process which includes practically all the R&D approaches which are usually covered under synthetic biology without using the label (see the »official« presentation of the strategy process in Wirsching 2011). One consequence of this is that the Federal Government stated in March 2011 in its response to a minor interpellation by the Social Democrats (SPD) in the German Bundestag that it has funded »no research and development projects to date specifically in synthetic biology« (Bundesregierung 2011, p. 2). The impression could be given that Germany is lagging behind in this technological field or is concealing its involvement, as was suspected promptly by critics (Testbiotech 2011). Neither appears very plausible – perhaps the BMBF has simply decided to wait and see whether the term »synthetic biology« really catches on in the long term or falls out of fashion in just a few years, to be replaced by a different buzzword in the biosciences.

At any rate, the BMBF is thus closer to the researchers in the natural and technical sciences who frequently – unlike many external observers – do not use the term synthetic biology at all in relation to their projects. And, when dealing with the potentials of synthetic biology, this almost antiquated refusal to use the fashionable term can be seen at least as a prompt to repeatedly ask what the common feature really is in the different R&D lines mentioned initially.

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GEOENGINEERING: COMBATING CLIMATE CHANGE WITH WHITE PAINT?

Global warming as a result of the steady rise in concentration of greenhouse gases in the atmosphere and combating the associated global problems with potentially catastrophic consequences represent one of the major challenges of the 21st century. The international efforts to counteract it by reducing greenhouse gas emissions have had little demonstrable effect to date. According to estimates by the International Energy Agency, CO_2 emissions reached another new record level in 2010 – following a slight decline in 2009, the year of the economic and financial crisis. Against this backdrop, there are growing signs that the debate about geoengineering interventions, which has mainly been conducted in academic circles to date, could clearly gain momentum and increasingly also reach the political arena.

The term *geoengineering* is less about a »new technology« in the sense of a fundamental technical innovation or a new branch of science forming a discrete research field. Rather, it is a collective term for methods and concepts – some of which have been available for a long time – whose aim, as set out in a frequently used but very vague definition of geoengineering, is an »intentional, large-scale manipulation of the environment« (Keith 2009). The actual new element in connection with the development of geoengineering technologies – which are *a priori* not at all restricted just to impacting on the climate – are thus not so much their technological principles, but rather the large scale of application of these technologies which has been announced. However, a precise and universally accepted definition which would enable unambiguous identification of which technologies and concepts with which scale of application merit the label *geoengineering* has yet to become established.

Against the backdrop of anthropogenic global warming, attention in recent times has been increasingly captured precisely by such geoengineering concepts which are intended to have a temperature-reducing impact by means of large-scale interventions in climate-related global cycles in order to check or even reverse the anticipated climate change. This ambitious goal is an indication of the necessary magnitude of these interventions – also termed *climate engineering* (CE) in this context and below: an intentional manipulation of the environment on a *global* scale. There is as yet no example in the history of human culture of a technology whose development and implementation could satisfy both attributes – *intentional* and *global* – whereas an example of a technology which is impacting *unintentionally* and on a global scale can quickly be cited: energy production based on fossil fuels whose unintentional consequence is the warming of the planet which is becoming ever clearer (Keith 2009).

The development of CE technologies differs from other technology creation routes in one further aspect: whereas new scientific findings combined with technical progress are often regarded as key drivers of new technology developments whose application fields and potential uses still have to be identified in some cases (please see in this regard the contributions on nanotechnology by C. Revermann and on synthetic biology by A. Sauter), the development of CE technologies can be interpreted as a search for solutions with a clear objective (reduction in the Earth's temperature). Against this background it should not be a surprise that in some cases long familiar technologies or – from a technical viewpoint – almost trivial concepts, though which are intended to meet their brief by means of a major increase in their scale of application, come under discussion.

At the same time the scaling-up of technologies to a global scale of application means that possible risks and/or unknown or unintended side effects and repercussions could also grow to the same extent. Earth's entire population may potentially have to bear the possible consequences and risks of the technology, with varying effects in terms of extent and time. Consequently, in the event of the development and large-scale implementation of CE technologies it is not just engineers and natural scientists who will face a major challenge, but also researchers in the humanities, social sciences and law as well as policy-makers.

POSSIBLE CLIMATE ENGINEERING TECHNOLOGIES

What concrete approaches and ideas can be placed under the heading of CE technologies? Differentiation of the technologies into interventions which influence the global radiation balance such that less short-wave solar radiation is absorbed by the Earth's surface or atmosphere and converted to heat (solar radiation management, SRM) and into interventions in the global CO_2 cycle with the goal of reducing the atmospheric CO_2 concentration (carbon dioxide removal, CDR) in order to eliminate the actual cause of global warming represents a systematic means of classification (in this regard and with reference to the following, Royal Society 2009).

INFLUENCING THE GLOBAL RADIATION BALANCE

In terms of influencing the global radiation balance, some of the solar radiation could be diverted into space using space-based systems before it even reaches the geosphere or, on the other hand, the reflectiveness of the Earth system (termed albedo) could be increased. The first category includes, for example, the proposal to shade the Earth by means of giant sun-shields to be positioned between the Earth and the sun to reflect or deflect the solar radiation. Assuming the shields can be precisely controlled, direct »weather control« would even become conceivable since the intensity of the solar radiation could be adapted regionally (Keith 2009).

In view of the enormous logistical demands involved in transporting the sun-shields to their destination, these concepts are pure science fiction at present. By contrast, the CE concepts for increasing the Earth's albedo, whose basically very simple principle is to make the Earth brighter overall, is easier to implement – even though it would entail appropriate efforts. The ideas, which are surprisingly simple from a technical viewpoint in some cases, include (Rösch et al. 2010; Leisner/Müller-Klieser 2010):

- Increasing the brightness of the Earth's surface – e.g. by painting roofs and roads white, planting fields and grasslands with more reflective plant types and varieties or covering deserts with reflective films;
- Enhancing the reflectivity of the lowest atmospheric layer (troposphere) – e.g. by artificially whitening low-lying marine clouds with the aid of sea salt aerosols which are sprayed into the clouds by unmanned boats;
- Enhancing the reflectivity of the atmospheric layer above the troposphere (stratosphere) – e.g. by delivering sulphate aerosols or aluminium nanoparticles, which help to scatter or reflect sunlight, into the stratosphere by means of aircraft.

The delivery of sulphate aerosols into the stratosphere is the subject of intense debate since it is already known from volcanic eruptions that sulphate aerosols in the atmosphere can generate a cooling effect (Crutzen 2006).

INFLUENCING THE GLOBAL CO_2 CYCLE

While the concepts for influencing the global radiation balance aim at compensating for the global warming caused by the greenhouse effect by reducing the net incoming solar radiation received, the objective of interventions for influencing the global CO_2 cycle is to stabilise or lower the atmospheric CO_2 concentration, and such interventions therefore address the root of the problem. One of the best known examples for CE in this category is the fertilisation of large areas of open ocean with nutrients (e.g. iron). The intention is to stimulate the growth of algae artificially, thereby fixing more CO_2 from the atmosphere in the algal biomass which would then – according to the theory – sink into the deep ocean with the dead algal biomass. The high level of awareness of ocean fertilisation methods compared with other CE proposals is a result of the fact that this is the only CE idea for which field trials have taken place on a significant scale to date – accompanied by public controversy over the legality and meaningfulness of these trials, such as the German-Indian »LOHAFEX« experiment clearly demonstrated in the spring of 2009.

A similarly simple proposal from a technical perspective provides for large quantities of biomass to be converted into stable carbon compounds (biochar) by heating in the absence of air in order to remove them from the natural cycle of biological decomposition. Regional concepts from the fields of agriculture and forestry, based on natural processes for sequestering CO_2 from the atmosphere, are also under discussion (Rösch et al. 2010): these methods, also collated under the term »climate farming«, entail, for example, afforestation, reforestation and avoidance of deforestation, conserving and expanding bogs or avoiding turning grassland into arable land in order to maintain or replenish the terrestrial carbon store.

Carbon dioxide capture and storage (CCS) from industrial flue gases and the direct removal of CO_2 from ambient air (»air capture«) with the aid of »artificial trees« are technically more challenging. Both processes presuppose that long-term, secure storage of large quantities of CO_2 in geological formations is feasible.

The CE proposals outlined – which do not claim to be exhaustive – can be classified according to their effort/effect ratio (Leisner/Müller-Klieser 2010):

- CE interventions with a small effort/effect ratio (which are also termed measures with a »large lever«) unleash a large and generally immediate effect with comparatively little effort and cost. CE concepts for increasing the reflectivity of the atmosphere and fertilising large areas of ocean fall into this category.
- CE interventions with a large effort/effect ratio aim to use a large input of labour and technical equipment in order to compensate for greenhouse gas emissions on a tonne-for-tonne basis or influence the radiation balance by changing the colour of the Earth's surface. This category includes the production of biochar, the creation of whole forests of artificial trees, the plan to paint all roofs and roads white and the proposed climate farming solutions. These interventions do not represent a quick fix for climate stabilisation since their implementation will

probably only proceed slowly and will require major effort.

It is generally believed that CE technologies with a large effort/effect ratio can be better controlled and monitored than interventions with a »large lever« (in particularly their use can be geographically delimited and halted faster in the event of unacceptable consequences) and entails fewer risks and side effects (Ott 2010; Rösch et al. 2010). In view of this, many scientists are of the opinion that only technologies with a »large lever« merit the term CE.

HOPE: PLAN B FOR EMERGENCIES

Mankind's long-standing desire to shape the environment or the climate in accordance with his own ideas and wishes by means of technical solutions is also addressed in the novels of Jules Verne (e.g. Sardemann 2010). In his novel »The Purchase of the North Pole«, published in 1889, for instance, the Baltimore Gun Club plans to shift the Earth's axis as a result of the recoil from a gigantic cannonball such that the polar ice of the Arctic could be melted, freeing the Earth's population at the same time from the annoying fluctuations of the seasons. The prospect of a more constant climate which would allow every citizen of Earth to live in a pleasant, stable climate zone initially results in worldwide agreement with and enthusiasm for the project. The Gun Club's action is, of course, primarily motivated by the goal of accessing the coal reserves thought to be under the ice and less by the prospect of helping mankind.

The technical optimism documented in Jules Verne's novels and fed by the rapid pace of technical development of those years may have awoken hopes of ultimately also being able to exercise control over the weather and climate thanks to scientific and technical advances. At that time no one suspected that the manipulation of the global climate had already started as an unintended consequence of precisely such technical advances – which we are experiencing ever more markedly today. The wish to shape our climate to suit our needs with the aid of large-scale technology-based interventions is thus now motivated less by mankind's desire to dominate nature, and more by the hope of having an emergency plan to safeguard our survival in the event that efforts to reduce greenhouse gas emissions fail.

The results of the international climate policy, which have generally been disappointing to date, really do make it doubtful whether the goal of limiting the rise in global warming to 2 °C above the pre-industrial level can actually be achieved by reducing greenhouse gas emissions. It is from this fear that many scientists derive their view that research into the opportunities and risks of CE interventions should not be a taboo subject but rather should be supported, even if it is usually emphasised at the same time that top priority must be given to the »classic« strategies for dealing with climate change – reducing greenhouse gas emissions (mitigation strategies) and adapting to climate change (adaptation strategies) – (e.g. Crutzen 2006; Royal Society 2009, p. ix). A weighty argument put forward by many proponents – known as the arming-the-future argument – states that is it almost a moral imperative to identify suitable CE technologies with minimal risks at the earliest possible stage in order to be able to offer future generations an optimum knowledge base for all possible actions and, if appropriate, also a last-resort, a »plan B«, against global warming (please see the box for a selection of pro and contra arguments).

The scientific interest in CE technologies could grow stronger still if is confirmed that »tipping elements« could represent an additional danger. These are critical subsystems within the climate system which could be switched into a qualitatively different state with potentially serious impacts if a system-dependent temperature level (the tipping point) were to be exceeded. It cannot be ruled out, for example, that a critical temperature level, which could trigger the continuing melting of the Arctic and Greenland ice, could be reached with global warming of less than 2 °C above the current level, i.e. possibly within this century. Additional solar radiation would be absorbed by the darker ocean and land masses, causing the rate of temperature rise to accelerate still further (ice-albedo feedback) – a development which could result in the complete disappearance of these ice caps in the summer within just a few centuries and a rise in sea levels by up to 7 m (Lenton et al. 2008).

The announcement by the Intergovernmental Panel on Climate Change (IPCC) that its fifth assessment report scheduled for 2013/2014 will for the first time assess possible impacts of CE proposals on human and natural systems and on mitigation cost, as well as evaluate options for appropriate governance mechanisms of CE options is an indication that scientists really are increasingly placing their hopes in potential CE technologies – because hopes are dwindling at the same time that the required reduction in greenhouse gas emissions can be achieved within the target timescale (www.ipcc-wg3.de/meetings/expert-meetings-and-workshops/em-geoengineering; 11.8.2011). It is to be expected that the issue of CE will therefore increasingly move into the focus of public discourse and gain momentum. NGOs and environmental organisations are already criticising the IPCC because the mere fact of describing possible CE technologies could push the actual target of emissions reduction further and further into the background (see also the moral-hazard argument in the box). This could ultimately further hamper the already difficult climate negotiations and increasingly exert pressure on the political decision-making process with reference to, for instance, funding programmes for CE research or to the licensing of large-scale field trials.

HYPE: CLIMATE PROBLEM SOLVED!

A possible and probable scenario for the ongoing CE debate could therefore be a rise in the number of those within the scientific community declaring themselves in favour of considered, internationally coordinated research into CE technologies in order to be forearmed and in a position to act in the event of an emergency.

However, a different scenario can also be pictured: CE technologies could be not only an emergency strategy but also perhaps a possible *alternative* to the classic climate protection strategies of avoidance and adaptation. It could, for example, be conceivable that research into and the development and deployment of CE technologies could be advocated not primarily by scientists but by the general public in view of the laborious and expensive efforts involved in avoidance and adaptation actions. The following framework conditions would underpin such a scenario, which is still purely hypothetical from today's perspective:

- Research results could show that certain CE technologies would offer a simple, effective and – compared with the classic strategies – very inexpensive and resource-friendly technical solution to the climate problem (efficiency argument);
- CE interventions would – compared with the classic strategies – be perceived as having far less impact on people's existing lifestyles and ownership structures, particularly in societies which are geared towards prosperity (easiness argument);
- As a consequence of global warming, climate-related environmental disasters causing major damage could occur regularly in future. This could increase the acceptance of CE technologies in light of the unknown risks (lesser-evil argument);
- Most CE concepts can be illustrated in very simple images and thus be easily communicated to the general public. The CE technologies with a »large lever« in particular really can be compared with the idea of the Gun Club from Jules Verne's novel in terms of their technical approach: pouring large quantities of iron into the oceans, delivering sulphur aerosols into the stratosphere by means of tanker aircraft, weather balloons or cannons (!) or painting all building roofs and roads white;
- In societies with a pronounced technical optimism far less attention would be paid to the possible risks and side effects, while the hoped-for benefit of the technology, on the other hand, would be greatly overestimated;
- Under certain circumstances »large-lever« CE technologies could be implemented unilaterally by individual states or special-interest groups with the corresponding resources. International consent would therefore not be a necessary prerequisite for the use of CE – those states which reject this action would be faced with a *fait accompli*.

The significant increase in media reporting of the CE issue in the last ten years compared with the 1990s indeed indicates that – in addition to interest among scientists – the public interest in CE technologies is continuing to grow (e.g. ETC 2010, p. 12). This could be interpreted as the first indication of a »hype cycle« (Konrad 2011, p. 157 f.): the positive expectations of what technology can deliver are gaining ever broader acceptance and are being rated ever more optimistically, accompanied by a strong increase in interest from the media. As a rule, such a »hype phase« culminates in exaggerated expectations which regularly prove infeasible in practice, at which point the expectant attitude disappears and the (public) interest settles back down. Only after this »disappointment phase« are the potentials of a technology assessed more realistically.

It seems plausible that none of the CE technologies has already peaked in terms of a comprehensive »hype phase«. If, however, it were to come to a marked level of public hype, which could easily take on global dimensions in light of the scale of use, the public pressure on political decision-makers would probably rise further still. The following quotation from US politician Newt Gingrich illustrates that this view is not entirely without foundation: »Geoengineering holds forth the promise of addressing global warming concerns for just a few billion dollars a year. Instead of penalizing ordinary Americans, we would have an option to address global warming by rewarding scientific innovation ...« (after ETC 2010, p. 14).

Interestingly, some of the proposed CE concepts have already undergone such a »hype cycle« *within* the science community. For example, the results of a series of small-scale trials of iron fertilisation of the oceans show that the initial optimistic expectations relating to the induced algal bloom and the sinking rate of the biomass were not achieved and consequently the effectiveness of the method has been

SELECTION OF PRO AND CONTRA ARGUMENTS ON CLIMATE ENGINEERING

Pro arguments

- *Arming-the-future argument*: We are morally obliged to examine every option in order to offer future generations the optimum basis on which to make decisions. Linked to this is the *last-resort argument*: we should prepare ourselves for emergencies so that unpopular options are also available.
- *Easiness argument*: CE is less difficult to implement in political and cultural terms than motivating people and industry to avoid emissions. Unpopular interventions in lifestyles, habits and economic ownership structures could be avoided.
- *Efficiency argument*: Direct and indirect costs of CE interventions are lower than the costs of avoidance and adaptation. It would be a waste of resources to prioritise avoidance and adaptation.
- *Lesser-evil argument*: The consequences of CE interventions, when compared with those of unrestrained climate change, could constitute the lesser evil overall.

Contra arguments

- *Moral-hazard argument*: The mere prospect of CE as the answer to our problems will cause many players to continue to emit large volumes of CO_2.
- *Termination-problem argument*: The use of CE technologies could give rise to a dilemma in future: if highly problematical side effects were to have occurred and, at the same time, the concentration of greenhouse gases were to have increased, future generations would be faced with the dilemma of either living with these side effects or bringing about rapid climate change by abruptly stopping the CE intervention.
- *Risk-transfer argument*: The risks caused by an economic model associated with high emissions will be passed down unfairly to future generations.
- *Informed-consent argument*: Actions with global and long-term impacts would only be legitimate if there were to be broad informed consent by those affected. Strictly speaking, that would be all people living now and in the future and would mean a legitimacy condition which can scarcely be met.

Source: according to Ott 2010

greatly overestimated. At the same time, it is becoming more and more clear that very little is known so far about the very complex interactions of maritime life and that the possible risks and consequential impacts of such an intervention are largely unknown (e.g. Strong et al. 2009).

FEAR: IT COULD ALSO GO WRONG

After the initial euphoria for the Gun Club's plan in Jules Verne's novel, the mood is quickly reversed once the news, review and feature pages of all the world's newspapers start to look into the side effects of the intervention: the flooding or creation of entire continents, climatic turbulences and the destruction of huge tracts of land as a result of the enormous recoil of the cannon, among other things, are expected. But by the time the governments of the world would like to halt the undertaking, the Gun Club has already started construction of the giant cannon in an unknown location which the rest of the world is unable to trace. The drama proceeds.

With reference to the »large-lever« CE technologies in particular, a comparable scenario of possibly frivolous unilateral action by private foundations, the world's richest individuals (Keith 2009) or governments acting in isolation does not seem to be plucked entirely out of thin air. Companies could also be tempted to such a careless use of these technologies in order to pocket a large profit in return for a small level of expenditure, e.g. by selling CO_2 emission certifications to which – if »negative« emissions of CE interventions in the CO_2 cycle were to be recognised in future within the framework of the market-based instruments of international climate policy – these companies would be entitled (Wiertz/Reichwein 2010). A glance at the large number of patent applications in the field, for instance, of technological solutions for biochar production, the manufacture of artificial trees or the optimum supply of nutrients for marine algae appears to lend support to the assumption that speculation on such a recognition of CE technologies is in progress (e.g. ETC 2010, p. 30 ff.).

The »large-lever« CE technologies in particular can entail significant risks and side effects which are not regionally limited because they intervene in sensitive cycles and could therefore have unintended impacts with, under certain circumstances, far-reaching consequences for environmental and socio-economic systems on a global level. A further cause for concern is the fact that the necessary field trials which would have to be conducted on a sufficiently large scale to eliminate any final uncertainties could themselves have unwanted and harmful repercussions which – given the complex interactions that pertain – could remain undetected for a long period or may not have their cause identified.

Sulphate aerosols, for example, once generated, can remain in the atmosphere for several years and display their effect. Possible risks and repercussions of the method – based on model calculations and observations following major volcanic eruptions – are addressed in the Royal Society's report (2009, p. 29 f.) (see also Crutzen 2006; Leisner/Müller-Klieser 2010):

- Global impacts on vegetation, forests, agricultural yields and the carbon cycle as a result of possible changes in the distribution of rainfall and wind and in incident solar energy;
- Modifications to the Asian and African summer monsoon, reducing precipitation and thus potentially impacting the food supply to billions of people;
- Reduction in stratospheric ozone;
- Some whitening on the sky;
- So far unexplored feedback mechanisms could have additional significant effects on atmospheric processes.

In addition to these specific risks, this method also shares the problems of all interventions in the global solar radiation balance: Since these do not eliminate the actual cause of global warming – the high man-made concentration of greenhouse gases in the atmosphere – the (negative) impacts associated with the high greenhouse gas content (e.g. acidification of the oceans) are not corrected; on the contrary, they are further amplified. In addition, the cooling of the climate by means of these methods would have to be continued over decades or centuries since halting the action would result in a sudden, rapid rise in temperature which would scarcely allow mankind to implement the then necessary adaptation strategies in good time (termination-problem argument).

In view of the possible global risks and repercussions of a technology which may have to be applied over several generations, a decision about deploying or not deploying it cannot be taken solely on the basis of technological and scientific criteria (feasibility, climatic effectiveness, environmental risks etc.) or cost considerations; rather, it also requires an evaluation based on ethical, socio-economic, legal (including international law), political and, possibly, other criteria. In fact, up till now, a technological/scientific perspective dominates, whereas research in the social sciences, humanities and law has only been addressing CE technologies in depth for just a few years.

The issues to be addressed by social scientists and legal academics are very ambitious. One issue to be discussed, for example, is the question of which body has the legitimacy and capability, in light of the potentially high risks and possibly based on an uncertain knowledge base, to take an accountable decision about the use or non-use of CE technologies in accordance with ethical standards. Such a decision would have to morally justify the fact that benefits and risks may well be distributed unevenly and that certain population groups could be affected more seriously by the adverse impacts for the benefit of others or that the problems caused today would be passed on to future generations (risk-transfer argument). But how could the risks (and opportunities) be communicated openly and transparently so that all those affected by the action can develop their own informed view and contribute actively to the decision-making process (informed-consent argument)?

Furthermore, there is no international mechanism which deals explicitly with CE or which could be applied in a comprehensive and legally binding manner to the various CE technologies. On the one hand, this is because CE represents a very heterogeneous group of technologies and there is as yet no definition on which a consensus might be reached. On the other hand, most CE concepts so far only exist as an idea or in computer models, and to date no one has seriously considered using the technology. However, the controversy surrounding the German-Indian »LOHAFEX« experiment of fertilising the ocean with iron, for instance, shows that there is a definite need for debate and action with reference to regulating CE.

Against the backdrop of transnational or global, possibly regionally differentiated, side effects and repercussions, the conventions based on international law, such as those negotiated in relation to earlier international climate and environmental polices, could act as a role model for such a global governance of CE technologies. At the same time, however, the climate negotiations of the past illustrate how difficult international agreement can be.

Furthermore, the fact that CE interventions could, under certain circumstances, be carried out by individual states or by small numbers of states in isolation would jeopardise the principle of consensus – a cornerstone of international climate policy (the targeted reduction in greenhouse gas emissions is only achievable in a joint show of strength). In connection with conventions on CE technologies, this principle would no longer have a key role to play: in particular, nations could claim national security interests as a reason for defying existing international norms and agreements, especially as these frequently tend to be more of a recommendation and less of a legally binding character (Wiertz/Reichwein 2010).

OUTLOOK

On the one hand, CE research, which has been dominated by scientists and engineers up till now, has already curbed the high expectations associated with certain technologies (e.g. iron fertilisation of the oceans); on the other hand, it has shown that – even if the technologies are simple in concept – potential side effects and repercussions can entail major systematic complexity and are largely not understood. The academic and public discourse, which has been technologically and scientifically based up till now, will increasingly benefit from research from the fields of social sciences, humanities and law since it is recognised that an evaluation of CE technologies requires contributions from every discipline. Various indicators allow us to conclude that the debate about CE technologies will gain momentum in the next few years and that the political pressure to make decisions and act could grow correspondingly.

With that in mind, TAB has been commissioned by the Committee for Education, Research and Technology Assessment of the German Bundestag to undertake a TA project in the field of geoengineering which will start in the summer of 2011 and is scheduled to be concluded in the autumn of 2012. The aim of the TAB project is, on the one hand, to provide a comprehensive overview of the current status of knowledge relating to scientific and technological aspects of the various CE technologies proposed with particular reference to possible risks and repercussions and, on the other hand, to develop and discuss the legal (including international law), ethical, socio-economic and political facets of the issue.

By the way, in Jules Verne's novel the effect expected from the cannon shot fails to materialise because of a trivial calculation error – the cannonball is sized far too small. The rejoicing citizens of the world keep their seasons, and disaster is not visited upon them. Let us hope, should it ever actually become necessary to use »large-lever« CE technologies, that no calculation errors are made!

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