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ORIGINAL PAPER

How Smart Grid Meets In Vitro Meat: on Visions as Socio-Epistemic Practices

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Abstract The production, manipulation and exploitation of future visions are increasingly important elements in practices of visioneering socio-technical processes of innovation and transformation. This becomes obvious in new and emerging science and technologies and large-scale transformations of established socio-technical systems (e.g. the energy system). A variety of science and technology studies (STS) provide evidence on correlations between expectations and anticipatory practices with the dynamics of such processes of change. Technology assessment (TA) responded to the challenges posed by the influence of visions on the processes by elaborating methodologies for a "vision assessment" as a contribution to what is now increasingly known as "hermeneutical TA". But until now, the practical functions of visions in the processes have not been explained in a way that satisfies the empirical needs of TA's vision assessment—that is to provide future-oriented knowledge based on the analysis of ongoing changes in the present without knowing the future outcomes. Our leading hypothesis is that we can only understand the practical roles of visions in current processes if we analyse them as socio-epistemic practices which simultaneously produce new knowledge and enable new social arrangements. We elaborate this by means of two cases: the visions of In Vitro meat and of the smart grid. Here, we interpret visioneering more in its collective dimension as a contingent and open-ended process, emerging from heterogeneous socio-epistemic practices. This paper aims at improving TA's vision assessments and related STS research on visionary practices for real-time analysis and assessments.

Keywords Future visions · Vision assessment · Visioneering · Technology assessment · Science and technology studies

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Introduction

Currently, the production, manipulation and exploitation of socio-technical visions are increasingly recognised as important elements in innovation and transformation processes, especially in science and technology studies (STS) and also in technology assessment (TA) literature on new and emerging technologies. "Visioneering", a term originally coined by the historian McCray [1] to explain the activities of creating and distributing visions in emerging nanotechnologies and space programs by particular groups of actors, has been further developed in the STS literature to indicate the emerging effects of diverse and complex societal and technological rearrangements, rather than single actions of single actors (e.g. [2, 3]).

For decades, a variety of sociological studies on the role of visions and expectations has provided evidence that dynamics of expectations and anticipatory practices—e.g. the use of visions for guiding issues—

correlate with dynamics of innovation processes (e.g. [4–6]). Visions are here seen as a constitutive key factor which influences the processes and at least enables innovations. However, these studies have also shown that the results of such long-term processes are explainable by reconstructing stabilisations and destabilisations of heterogeneous actor networks in which visions play different roles, have different effects and are changing themselves ([7, 8]). In order to grasp the future orientation in TA and serve in governance advice, the model of vision assessment has been proposed by Grunwald and others as a tool to analyse, to assess and to shape the use of such visions in debates and controversies [9]. In his more recent approach, Grunwald is focusing more and more on a hermeneutic of "technology futures" in order to understand the assignments of meanings to technologies and their potentials produced by certain actors by means of future imaginations (e.g. visions), which can be found in current discourses in scientific, policy and public arenas.[1] This should enable TA to enlighten policy and public debates by providing a contribution to support responsible innovations [11].

Although these perspectives are useful, we think that until now there are some important aspects and functions of visions in innovation and transformation processes that have not been included in a way that satisfies the empirical needs of TA's vision assessment. TA has to analyse and judge trends in science and technology as well as their societal aspects, contributing to the formation of public and political opinion on these aspects. Traditionally, TA examines the state of the art of the relevant scientific and technological branches involved in these processes and tries to evaluate the potential risks and benefits. In contrast to research which starts with the outcomes and *reconstructs* the initial dynamics in socio-technical constellations, TA and its vision assessment are committed to analyse and evaluate the role of visions and visioneering activities in *current* socio-technical constellations in order to identify needs to intervene in such early stages of (potential) socio-technical change which could manifest in an unknown future. Although no one can know what the future will look like, for TA, it is important to be able to identify the constellations in the present which create spaces of possibility from which potential future impacts of innovation and transformation processes emerge. In other words, TA is committed to disentangle the possible effects on broader innovations or transformations (e.g. new technological fields, socio-technical systems) in the future. Therefore, TA needs a framework for grasping what imaginations and representations of the future today do in practices, namely in existing socio-technical arrangements and ongoing processes. We believe that this empirical focus on visions as practices should be the starting point for such an assessment. The analytical gaze would thus contribute to meet the demands of TA, and it would enrich the STS models, especially of the sociology of expectations, in particular with regard to examinations of the present.

The leading hypothesis of this paper is that we should integrate the analysis of visions as *socio-epistemic practices* into technology assessment—practices which simultaneously produce new knowledge and enable new social arrangements in different socio-technical constellations. Such practices of knowledge production and of creating new actor positions and social orders can enable innovations in established constellations or their transformations. To show this, we will sketch and compare two rather different cases assuming visions at work as socio-epistemic practices. One case is related to the discursive practices of generating In Vitro meat (IVM) as an innovation in food production. It will be shown how visions are needed to produce connections between the new, not yet established and unfamiliar IVM, the existing socio-technical arrangements of meat production and consumption and sustainability and ethical discourses. The other case is the experimental practice of transforming the energy system through envisioned smart grids. Here, it will be shown how visions of smart grids are used in tests and for the creation of new socio-technical arrangements in experiments which seem to be necessary for a decentralised energy production and consumption under digital control in the future. In both cases, visions play an important role in the practices which are needed to produce the knowledge and the social arrangements which could be a precondition of change.

The two cases are rather different concerning both the envisioned socio-technical innovations and the affected actor constellations. We assume that it is the confrontation of different practical roles of visions that is helpful in such cases to explain the various ways in which visions can function as socio-epistemic practices in ongoing and unstable processes. These processes can, but

[1] Grunwald's concept of "technology futures" has nothing in common with prognoses about what the future of a technology will look like [10, 11]. We agree with this understanding of "technology futures".

do not necessarily have to, lead to comprehensive innovations and transformations. Our paper is a critique of too naive an understanding of visioneering as a steering process based on intentional strategies of actors. It is a contribution which helps to conceptualise visioneering as a collective process emerging from heterogeneous and interrelated socio-epistemic practices. The paper aims to improve the theoretical and methodological approaches of vision assessment in TA, in particular with a view to real-time assessments. Furthermore, it may enable STS to better examine the productive role of visions in current processes of change, which cannot be completely explained by the existing theoretical models originally developed in retrospective case studies. Our paper tries to shift the theoretical view to the levels of knowledge production and the production of social arrangements which are, as we argue, both enabled through visions as socio-epistemic practices in the different practical contexts of innovation and transformation processes.

Visions as Socio-Epistemic Practices

We can find many different ways of dealing with the future dimension of technologies in STS and TA literature on innovation processes and technological development. What we claim is that, despite their richness, these different suggestions leave a blind spot for the specific analytical challenges offered by uncertain and unstable phenomena which could, but do not have to, result in the emergence of new technologies and innovations with far-reaching impacts on society in the future.

Activities of visioneering in the sense of steering the creation of new technological fields and innovation processes by the agenda setting of powerful actor groups have raised increasing attention in STS debates on technosciences. As already mentioned in the Introduction, the historian McCray [1], for example, argues that the emergence of nanotechnology as a major field of US research policy was as an effect of the earlier invention and communication of nanotechnological visions by a small group of scientists around the nanofuturist Eric Drexler. Sociologists and philosophers discuss the role of European Union expert networks in the creation of technosciences such as nanotechnology and also criticise how visioneering is used for setting up new technoscientific research and funding fields (e.g. [2, 12]). From the literature on visioneering, we have learned that a number of new technologies owe their development to the successful activities of visioneers. However, attempts to steer research and development processes by means of visions are not a new phenomenon in the course of technology development in modern society, as has been shown in decades of sociological research on the role of visions for guiding communication and coordination between the involved engineers, politicians and others (e.g. [13, 14]).

In the 1990s, German social scientists introduced the concept of "Leitbild" to describe visions associated with the design and implementation of new technologies. "Leitbilder" serve as a reference framework for the involved actors (the so-called "guiding function"). Through providing an integrative imaginary (the so-called "image function"), they serve as an activating, mobilising and stabilising reference point for the innovation process [13]. From Leitbild research, we have learned that visions are capable to coordinate different actions in technological development. Later, the sociology of expectations described how influential and powerful visions can be in debates about innovation processes (e.g. [6, 15]). For example, dynamics in collective expectations may lead to a degradation of former powerful futuristic visions (e.g. [5, 16, 17]). This revealed important correlations between visions and innovation processes. The strong orientation towards the future of visions and their broader and more ambiguous character (with respect to the examples analysed by the German Leitbild theory), especially in the field of new and emerging technologies, led to Grunwald's concept of vision assessment in TA, a method to analyse, assess and shape the use of such visions in debates and controversies [9, 11]. By now, there are quite a few TA papers on the communicative, discursive functions of such visions and also on their normative implications (e.g. [18–20]).

Taken together, these heterogeneous approaches show that visions play constitutive roles in innovation processes and the accompanying societal debates. Furthermore, they show that dynamics related to certain visions can be really contingent; in this sense, they do not offer evidence of visioneering as a steering activity. Looking back on past processes in the emergence and development of technosciences, it seems more plausible to speak about visioneering as a collective and open-ended assemblage of activities [2, 3].

One of the most prominent theoretical approaches to analyse the role of visions in practical arrangements is the original translation model of Michel Callon in actor-network theory [21, 22]. According to this concept, visions are only suitable for steering innovations and transformations if they "survive" in the constitutive steps of creating and transforming actor networks, which are the steps of "problematisation", "interessement", "enrolment" and "mobilisation" (ibid., see also [21], and, applied to the case of nanotechnology, [17]). Ups and downs in innovation processes and the corresponding upgrading and downgrading of visions by changing collective expectations can be explained by the reconstruction as hype and disappointment cycles, which are said to be typical of most innovation processes (e.g. [5, 6]). However, the starting points of this sociological research and especially of the translation concept in actor-network theory (ANT) refer to developments which have been stabilised or institutionalised in the present. Their unclear historical emergence has to be explained by reconstructions of the translation mechanisms, which destabilise constellations in certain stages of the process and thus allow new constellations in more complex and longer-term processes. This model and similar approaches are heuristics originally developed by reconstructions of historical processes. They make sense of heterogeneous and non-linear changes which can be observed by looking back. From this perspective, the contingency and complexity of the activities of visioneering in relation to the dynamics and outcomes of long-term processes of innovation and transformation can be explained.

In contrast to the retrospective efforts of these studies—that is to explain the possibility of current outcomes by reconstructing their history—we are in STS and in TA research often confronted with unclear and instable phenomena, such as assemblages of new inventions, actors, promises and visions, which may eventually lead to innovations in the future by somehow influencing the processes. Especially TA is called to assess these instable phenomena of potential change. As mentioned above, for this reason, TA (in particular in Germany) has developed its vision assessment approach and calls for a stronger hermeneutic interpretation of future visions applied in societal debates and controversies (see [10, 11, 23]). But up to now—in contrast to the focus of many STS research projects on the deep entanglement and co-constitution of visionary ideas and practices (e.g. [4])—TA's vision assessment is focusing mainly on assessments of the contents of visionary narratives and imaginaries and their evaluation against their expected feasibility and their societal desirability. From our point of view, this focus needs to be broadened for TA to fully grasp the roles, functions and effectiveness of visions in visionary practices as parts of innovation and transformation processes.

For these reasons, we[2] elaborated the concept of visions as socio-epistemic practices to offer a new empirical approach for a vision assessment in TA, which is able to analyse and assess the practical and enabling role of visions. This approach aims to explain how visions become practically effective in certain contexts of current processes and what their effects are, without knowing their final outcomes. This approach can demonstrate how visions produce meanings as well as orientations for actions and decisions by imaginatively and practically rearranging existing knowledge, technologies, actors, forms of organisation and communication.

Generally, it can be stated that visions are representations of the future and narratives in which already known technological trends and societal constellations are rearranged around a vague point in the future. They are practices which produce the normative premises about the desirability of the provoked change and which culminate in expectations and promises, as the sociology of expectations has shown. However, what is important for us is their empirical function. Therefore, it does not make sense for this kind of approach to offer an a priori definition of a vision since the essence of visions as socio-epistemic practices emerges from their functions. We recognise the following functions:

- Visions *serve as an interface* which allows translations between present constellations and the future and thus open up imaginative and practical possibilities.
- Visions *work as communication media* between different actors and discourses to which all the involved or addressed actors can refer, even if they have very different interests and perspectives.
- Visions can serve in different discursive and other practical constellations as means that *enable*

[2] These ideas were also elaborated in the project "Visions as socio-epistemic practices. Theoretical foundation and practical application of vision assessment in technology assessment" at ITAS, to which the two authors belong. See https://www.itas.kit.edu/english/projects_loes14_luv.php. Accessed 20 July 2016.

coordination, because they are a reference point to guide different and heterogeneous activities.

- Visions motivate because they *develop a normative force*; the envisioned and proposed emerging innovations are presented as the best and most feasible solution to current and/or future problems or challenges. Therefore, they tend to exclude alternatives solutions of the described problems.

With our proposal, we do not argue that other approaches did not consider these characteristics of visions in their analysis. For example, Adam and Groves [24] pointed out how visions could construct an interface between present and future in communication processes. In our previous research, we showed that visions enable communication between heterogeneous actors and action as media (e.g. [25, 26], which is similar for Leitbilder [14]). For such mediating and enabling functions of visions, we can also refer to the research on knowledge objects (e.g. epistemic things, [27, 28], or boundary objects, [29, 30]). Much other STS research could be mentioned here. However, we think that the strength of our analytical approach of visions consists in bringing these different aspects together—in a systematic and functional manner—in order to understand how visions produce and designate spaces of possibility, how they normatively translate the use of the spaces of possibility into an urgent need for the current society and finally result in practical changes in the socio-technical arrangements and constellations they address.

Furthermore, we think that the practical effectiveness of visions is correlated with the type of socio-technical constellations in which they are used and in which the innovation can take place. These constellations are very different in our two cases. In the In Vitro meat case, we ask how visions are practical parts of the generation of IVM as an innovation for a sustainable future and thus enable the production of new social arrangements which did not exist before. In the smart grid case, we ask how the visions work as functional elements in experimental practices which test the possibilities of rearranging existing socio-technical constellations of the energy system to potentially match the innovations in the electricity grid brought about by smart grids. In both cases, we see visions as socio-epistemic practices and can identify the interplay of the four above-mentioned characteristics. In the following, we will elaborate on the different ways in which visions work in these two cases but also show that their practical use is in both cases essential for changes. The different practical constellations in which visions unfold their functions as socio-epistemic practices are explained by discursive practices of visions in the case of In Vitro meat and by experimental practices of visions for the smart grid in the energy transition.

Envisioning In Vitro Meat as the Best Solution for a Sustainable Future[3]

IVM is meat grown in a culture medium using the techniques of tissue engineering instead of being taken from living animals. In the first step, muscle cells are obtained from an animal from a muscle biopsy. Then, they are grown in a petri dish with the help of a growth medium. In this way, the muscle cells are able to assemble forming muscle fibres and then muscle tissue in a so-called bioreactor [31].

Although the idea of IVM was first imagined in 1927 by John B.S. Haldane and, more concretely, in 1931 by Winston Churchill and was materially researched in NASA laboratories in the 1950s, this research became only feasible in the 1990s through the development of different branches of biology, namely stem cell biology and tissue engineering. The first patent for a method producing In Vitro meat is dated 1997. Five years later, the first In Vitro grown tissues were created by two different groups; a scientist group at NASA created fillets of *goldfish* muscle tissue and announced it in a scientific publication [32], and a bioart group presented muscle tissues grown using foetal sheep cells in different exhibitions with the intent to invite the public to reflect on the implications of using medical technologies for non-medical needs [33]. Both activities remained largely unnoticed by the general public. It was not until the activities of dedicated scientists, charities and private investors that the idea of producing meat through the means of tissue engineering became a vision attached to a particular message concerning sustainability, ethics and future food.

In 2004 the *New Harvest* charity was established with the goal to "strategically fund and conduct open, public, collaborative research that reinvents the way we make animal products—without animals", as stated on their website. One year later, the Dutch Government

[3] Some analyses in this section have been conducted in the "Visions of In Vitro meat. Analysis of the technical and social aspects and visions of In Vitro meat (VIF)" project, funded by the German Ministry of Research and Education (https://www.itas.kit.edu/english/projects_ferr15_ivf.php). For more information, see the project website in German at http://invitrofleisch.info/.

decided to support research through a set of PhD studentships at different universities (supervised by the Maastricht-based physiologist Mark Post), and in 2009, it approved further funding at two universities. During these years, other research groups, in Norway, Sweden and the USA, decided to work on this innovation, such as for example the *Modern Meadow* start-up dedicated to the development of the biofabrication process (three-dimensional printing technology) for creating In Vitro meat and In Vitro leather. In 2008, the strategic alliance with the very well-known and influential animal rights organisation People for the Ethical Treatment of Animals (PETA) promoted the vision of IVM as a solution to the problems concerning the production and consumption of traditional meat; PETA decided to support this innovation, announcing a US$1 million prize for the first commercially viable In Vitro chicken meat and then funded a 3-year post-doc research position in this field. The prize money was never released because the deadline of 2012 was not met, but PETA still supports this research. Their decision has opened the door for new alliances between researchers on methods of producing meat and animal rights/animal welfare organisations and thinkers who would have otherwise remained separated.

The above described activities of stimulating research and attracting interests from different non-governmental organisations and investors between 2004 and 2012 culminated in a multilayered strategy of catching public attention. On 5 August 2013, the research team around Mark Post at the University of Maastricht, the *New Harvest* charity and some big investors, such as the Google co-founder Sergej Brin, co-organised the launch of the first In Vitro burger made entirely of bovine stem cells in London at a hybrid science-media event (something between a cookery show, a press release and an experiment [34]).[4] This event was introduced with a short explanatory film created by the *The Department of Expansion* media production company (still visible on YouTube), which was also shown at the launch of the "cultured beef"[5] project at the University of Maastricht. In this video, different experts, namely Brin himself, an evolutionary anthropologist (Richard Vrangham), an environmental scientist and activist (Ken Cook) and Post, all point out the devastating effects of meat on the environment, although underlining its historical and evolutionary importance. In the film, the dilemma of today's meat is presented as potentially solved by the development of technologies like tissue engineering, which make it possible to grow meat without killing animals. As O'Riordan et al. [34] have noted, this hybrid media event played a central role in constructing the meaning of this innovation, since no culturally available definition of this innovation existed before. This video, which made the vision of IVM tangible, worked as a strong *communication medium* between different actors and discourses, which previously remained separated, the environmental concerns for the health of the planet, concerns for the treatment of animals and, at the same time, the praise of meat as a central nutrient in human diet. The centrality of meat is, however, something which has always been doubted from a cultural and nutritional point of view by organisations supporting vegetarianism and veganism. Furthermore, this video accomplished the construction of an object of tissue engineering which was previously only known and debated amongst specialists in tissue engineering or stem cell research, as the instrument for solving the sustainability challenges of tomorrow's food. Redefining its ontology, In Vitro meat became a vehicle for communicating differently about sustainability strategies after 2013.

The film shown at the London event also marked some sort of linguistic shift in the very definition of this innovation; in this video, the term "In Vitro meat" is not used, but it is rather spoken of (conventional) meat as muscle and of the burger as "meat just not in a cow". The scientific project at the University of Maastricht for which the film was produced is called Cultured Beef. Also, the *Modern Agricultural Foundation*, founded in Tel Aviv in 2014 with the aim of pioneering the research on lab chicken meat worldwide, and Andras Forgacs of *Modern Meadow* referred to this innovation [35], highlighting its progressive role for the production of future food. In a recent publication on this innovation, targeting again the broader public and freely available on the Internet, Isha Datar [36], Chief Officer of *New Harvest*, explains the reasons for preferring the term "cultured meat"; the reference to "cultured" is not only scientifically more accurate (it will not necessarily be produced In Vitro but under safe laboratory conditions) but also develops a sense of familiarity with activities in the food context, such as fermentation of bacteria (making yoghurt) or of yeast (brewing beer), which have been known for centuries. Furthermore, the term "cultured" indicates the ethical added value of this innovation, "This meat is 'cultured' because it is environmentally considerate, sanitary,

[4] See an extract of this media event here, https://www.youtube.com/watch?v = bkbLVamdUEY. Accessed 20 July 2016.

[5] The culturedbeef.net website went online in July 2013.

healthy and humane. Many would argue that cultured meat would be the only ethical meat. By convenient coincidence, cultured implies that this meat and the people who consume it are enlightened, civilised and of discerning tastes" ([36], p. 20). In other words, for Datar [36], cultured meat is the result of a development in science and technology that permits the application of tissue engineering principles to fermentation for the first time, and it is a step in the advancement of civilisation. In January 2016, the San Francisco-based *Memphis Meat* start-up released a video in which they showed the "world's first cultured meatballs" being fried in a pan; they also avoid the use of the term "In Vitro".[6] In the video, the chief executive of *Memphis Meat*, Uma Valeti, declares that his company's approach also produces 90% fewer greenhouse gas emissions than traditional agriculture, and the woman who tastes the meatballs declares that the product is "good" and "tastes like a meatball." In this article, we use the term "In Vitro meat" since we want to have a more detached and critical view of this innovation, without necessarily positioning ourselves for (or against) this vision. By using the label "cultured meat", this innovation might appear too favourable since the reasons for using the term "cultured" are clearly to put this vision in a progressive, positive light.

Over the last couple of years, IVM has been more frequently labelled in a broader and more appealing way as "post-animal bioeconomy" or "cellular agriculture"; these terms, coined by *New Harvest* at the end of 2014, refer to a new field including tissue engineering, stem cell biology and in some cases also synthetic biology and genetic engineering, dedicated to produce animal products without using living animals. The best-known innovations are IVM, milk without using cows and egg whites.[7] We do not want to go into too much into detail explaining the other innovations regarding a post-animal bioeconomy—what is interesting here is that the practices of defining these innovations are conceptualised as part of the bigger and successful sustainable food movement, in which the interests of the environment, of the animals and of the human beings can be successfully taken into account (for an analysis of these labels, see [37]).

Through this brief reconstruction, we can see that IVM has become a vision, intended as a practice capable of creating new meanings and new narratives linking topics which were previously regarded as separate. The non-medical use of a medical technology such as tissue engineering paves the way for creating food security and ethical conditions in food production. From the very beginning, the idea of IVM has been to produce "exactly the same meat" (as Post explained in the video launched in London) without using the entire animals; in this way, many downsides of the traditional meat production can be avoided, such as the pollution of water and land, the use of vast amounts of land to keep the animals, and the problems for human health due to antibiotics and other substances given to animals. Furthermore, animals do not have to be killed in the process of producing IVM and they suffer much less (since the muscle biopsy is described as a minimal invasive procedure) (see, amongst others, [38]). Therefore, from the start, IVM has been launched as a vision promoting a "win-win" solution for future food since it will be good for the environment, for human health and for the animals.

IVM is, in general, a vision which aims at reconsidering the way in which we think about food, meat and animals. It is not only an innovation that expresses different promises and expectations, as researchers from the sociology of expectations would say [39]; it also acts, empirically, as an *interface*, allowing translations between current problems of traditional meat production and consumption and images of the food of the future. This role as interface is constructed with the help of data which is based, on the one hand, on provisional and hypothetical data and scenarios and, on the other hand, on concepts which are often incomplete and tend to focus on selected aspects. Currently, IVM cannot be produced on a mass scale, and therefore, nobody can know, for example, its exact environmental footprint. The ecological advantages of this innovation are explained with reference to a life-cycle assessment paper by Tuomisto and Teixeira de Mattos of 2011 [40], in which they calculated substantial advantages of In Vitro meat compared to conventional meat regarding land use, water use and green gas emissions. The charts of this paper are often shown in presentations by the main actors, although the authors themselves described the limitations of their model in later publications and despite more recent

[6] See the video at https://www.youtube.com/watch?v = Y027yLT2QY0. Accessed 20 July 2016.

[7] The company *Clara Foods* is working on producing egg whites with synthetic biology methods avoiding the use of hens.

and accurate results which point out significantly lower ecological advantages. It has been shown that this innovation would require more industrial energy than the conventional production of pork and poultry [41]. Arguably, this repetition of favourable data and the focus on a selection of them are typical for the process of constructing visions. The idea of the ecological potential of IVM is not only an expression of promises but also a practice capable of influencing debates and, in the long run, future sustainability scenarios. Indeed, IVM is emerging as one of the possible pathways in designing food politics. For example, Bonny et al. [42] have elaborated different scenarios in which they anticipate the changes of the future meat industry by comparing In Vitro meat with traditional meat, which they call "manufactured meat" (with which they mean plants and mycoproteins), insect proteins and modified meat derived from genetically modified and cloned organisms.

IVM presents itself as an ethical innovation and, right from the beginning, shows its strong *normative force*. IVM is described as ecologically advantageous, sketching a better future for humans as workers and food consumers and for animals [43, 44]. Forgacs [45] and Datar [46] imagine breweries and vertical farms operating in many urban contexts in which meat can be produced without any contact with animals, in absolute transparency under safe and sterile conditions. These places could be toured like beer breweries or ice-cream factories and can be put back into urban centres, not marginalised at the periphery; their cleanliness and advantages should be celebrated and exposed, not hidden as it was the case with slaughterhouses. They are presented as places in which artisans, craftsmen and microbiologists work, not exploited slaughterhouse workers [46]. Moreover, it is permanently repeated that animals would not have to die for the meat production and that this would be an enormous contribution to protecting their welfare.

The normative force of the IVM vision as a practice capable of influencing debates and policy discourses is enacted as a balancing act between possible advantages and the many unknowns of the future. Innovators see only advantages in their idea; they tend not to speak of, or at least minimise the presence of disadvantages. If they are addressed at all, they are previously selected. Technical difficulties or problems of acceptance are then described as challenges and possible disadvantages (such as future accessibility of this innovation on a global scale and its distribution), and potential human or animal health threats are not openly discussed. Despite the fact that innovators insist on the avoidance of antibiotics for the mass production of IVM and thus praise the sterile and safe conditions of a production in the lab, the burger presented in London was created using antibiotics [47]. Moreover, since the connection between meat consumption and augmented risks of suffering from certain diseases has not been fully clarified in the scientific literature, and since no projection of the level of consumption of IVM in the future is possible, it seems a little risky to state for sure that IVM will only have health benefits. Concerning the animals, although it is true that there will be no need to kill them for obtaining cells, it remains unclear how and where they will exactly live in the future and thus whether the new conditions will be compatible with the protection of their welfare [48]. If we take a closer look at all stages of the production process, such as how the cells are obtained from the animals and what the lives of the animals providing these cells are like, the picture becomes less bright. The topic of human-animal relationships in a future world with IVM is rather seldom part of the message of innovators who prefer to focus mainly on the advantages which come directly from IVM as a product. For Post, the important issues to consider in order to further develop this innovation are the "scalability of the production process, quality control of mammalian cell/tissue cultures, maintaining sterility in the culture, prevention of contamination or disease and the controlled breeding of stem cell donor animals" ([38], p. 300). In this way, animals will no longer be used as direct sources of meat, but they will be optimised in their function as stem cell donors. However, much of the hopes of the supporters in the animal welfare/rights and liberationist movements are placed in the possibility to entirely overcome the use of animals. Many of them expect that animals could live free or in human companionship (see the vision of the "pig in the backyard" as a result of the empirical work in a focus group in [49]). At the moment, the lack of animal components is not even granted, since in the production process of In Vitro meat, the foetal calf serum is used as growth medium.[8]

The *normative force* of IVM as a perfect solution for the environment, human beings and animals is also constructed by means of marginalising the alternative solution of plant-based products. Despite the fact that the innovators state that a total stop of eating meat would be the best solution for the environment, they describe this option as not feasible due to the centrality of meat in human history; Post describes vegetarianism in different talks as the most sustainable option, but as not the most realistic one (see, for example, [31]), adding that the number of vegetarians has not grown over the last 35 years (although new statistics show the opposite). Datar often starts her speeches by praising the nutritional values and taste of meat (see, for example, [36, 46]) and then argues that these advantages nowadays come with a price which we cannot pay in the future. The open future of meat, which is developed from the idea that the current levels and ways of producing and consuming meat have no future and should be changed, is closed through the proposal of IVM as the future solution for all the meat eaters. IVM is not primarily aimed at reaching vegetarians and vegans but meat eaters who do not want, or cannot become vegetarian.

As already stated, the vagueness of this vision is at the same time a strategic choice and an unavoidable element of many innovations. The vision of IVM enables the *coordination of different activities*, from research projects to the involvement of different and previously rivalling social actors. Animal rights and liberation movement activists now partly agree with the pragmatism of IVM innovators. The vision of In Vitro meat is constructed as the way to meet different needs of different communities which express different ethical values, such as concerns for animals and attachment to meat, which previously remained irreconcilable. For example, some of the innovators of IVM do not see intrinsic ethical problems in meat consumption (and thus in killing animals) but see it as a problem how animals are raised in modern agricultural production, including the negative environmental impacts of such production. On the other hand, actors such as PETA, recently the *Sentience Politics*[9] think tank, and even ethicists who condemn meat consumption on ethical grounds (such as, for example, 51) as well as vegan Chief Executive Officers (CEOs) of start-up companies in the post-animal bioeconomy (like the CEO of *Muufry*, a company which is dedicated to the development of milk without cows), are all united in supporting IVM for pragmatic reasons.

The rearrangement of previous social orders concerning meat clearly demonstrates that all kinds of technological innovations, despite their novelty, come at the price of reinterpreting old topics, not only because IVM wants to substitute meat but also because in the process of determining its ontology, it redefines the scopes and the role of (conventional) meat itself. It is indeed impossible to talk of and reflect on In Vitro meat without doing so on (conventional) meat. Inasmuch as In Vitro meat remains an object "ontologically undefined" [39] and "in search of identity" [52], it also shapes the ontology of meat, because it forces the consumers to think about their real motivations to consume meat: is it only about taste? Or it is about nutritional value? Or domination of nature? The decisions of some actors in the animal rights and animal liberation movement to support IVM are hardly contested by others in the movement; Simonsen [53] and Miller [54], however, point out the risk that this innovation could annihilate the subversive cultural potential of vegetarianism and veganism in which a particular nutritional style is only the appendix of a larger critique of society.

In this section, we explained how the analytic tool of visions as socio-epistemic practices can be applied to the analysis of IVM as innovation at an early stage. In the next section of our article, we will compare the most important elements of this

[8] Scientists in the field of In Vitro meat as well as in fundamental biology are working on an animal-free alternative to foetal calf serum, since animal compounds represent a health problem (it has been demonstrated that these serums can transmit diseases) and an epistemic one, rendering experiments less standardisable (it is often impossible to trace the origin of the calves from which the serum is extracted). For an ethical innovation such as In Vitro meat, the use of this serum represents a serious problem, since the procedure of obtaining it is painful for the calves [50]. Nevertheless, it is interesting, and also quite typical for an enthusiastic innovation narrative, that the positive effects of In Vitro meat on animal welfare are often stated without mentioning this problem.

[9] *Sentience Politics*, which is part of the *Effective altruism* charity based on the ideas of the philosopher Peter Singer, has recently written an open letter to the German Government asking for financial support for research on IVM (see https://sentience-politics.org/de/politik/kultiviertes-fleisch-deutschland/). Accessed 19 July 2016.

analysis with the ones gained from an analysis of the vision of a smart grid.

Envisioning the Smart Grid as the Solution to the Challenges of the Energy Transition[10]

Engineers and IT experts define the vision of a future smart grid as "a vision of a future electricity grid, radically different to those currently deployed, where the bidirectional flow of both electricity and information allows demand to be actively managed in real time, such that electricity can be generated at scale from intermittent renewable sources. […] Unlike existing grids where electricity generally flows one-way from generators to consumers, [the smart grid] will result in flows of electricity that vary in magnitude and direction continuously" ([56], pp. 86–89). This change should be enabled through a massive integration of information technologies in the electricity grid, which implies a digitisation of the whole grid. Depending on the actual definition of a smart grid, this might include novel internet technologies, smart meters, smart homes, electric vehicles and refrigeration systems as energy storages and smart markets for flexible charges or otherwise becoming "smart". These are elements and components that would integrate all parts of the energy system into a socio-technical system of producers, consumers, markets, regulations, technologies, etc., into a kind of energy internet (e.g. [57–59]). Overall, the smart grid is therefore envisioned as a kind of "artificial intelligence" which will coordinate and regulate the interaction of all components and processes of the electricity sector in the future ([56], pp. 86–89).[11]

This vision of a future smart grid is getting a lot of attention in the context of the transformation of energy systems—especially in the German energy transition. The German energy transition is an ongoing process of transformation of a complex "socio-technical system" (e.g. [63]) and infrastructure, where we do not know today whether the effects of this process will meet the aims of a nuclear phase-out and massive integration of renewable energies as substitutes for fossil fuels, proclaimed by the German Government in 2011 [64]. It is clear to many external observers of the German energy transition and actors involved in the processes of change (e.g. energy suppliers, local utility companies, consumer organisations, regulatory bodies) that such a transformation will rearrange many elements, functions and processes in the electricity sector. Especially the integration of substantially more renewable energy will lead to the decentralisation of the old, established and centrally controlled "energy system" due to the volatility of renewables and more regionally distributed generators. This decentralisation has been discussed as resulting in a destabilisation and loss of control in electricity supply (e.g. [65–67]).

Here, the vision of the smart grid comes in. The future smart grid—as described above—is envisioned as a solution to these problems. The vision relies on the idea that this tool will integrate the dispersed elements and functions and enable a new stability and control through flexible regulation of the future energy system (e.g. [56], pp. 86–89). In its decision on the energy transition, also the German Government sees the smart grid as a solution to the problems caused by the reorganisation of the energy system and as one of the central enabling conditions for the desired changes. It argues that in the future, "demand-side load management is to adapt energy demand more closely to supply" and that this "calls for state-of-the-art intelligent grids", which "will manage electricity generation,

[10] Some of the contents of this section have been discussed in more detail in another publication [55]. In this other publication, the empirical results are interpreted using Foucault's concept of "apparatus" however, and not as indicators to understand visions as socio-epistemic practices. The empirical work consisted of a document analysis and qualitative expert interviews conducted within the research project "Systemic risks in energy infrastructures", one of the projects of the Helmholtz Alliance ENERGY-TRANS (http://www.energy-trans.de/english/68.php). Accessed 19 July 2016. The document analysis included policy documents issued between 2007 and 2014 on the energy transition and smart grids mainly in Germany but also in the USA. Furthermore, it considered scientific texts on smart grid technologies from 1997 to 2014. In addition, a series of qualitative expert interviews was conducted in 2013. These included experts from power supply companies, an association of local utility companies, an industry association, an environmental association, a consumer protection association, technology companies and scientific experts, especially economists.

[11] Historically, the vision of a smart grid is not a result of national and international policy decisions on energy transitions. The smart grid vision emerged in the 1990s in engineering circles (cf. [60]). Many of the technological components under consideration were already in development before the German Parliament's decision, but their implementation in the energy system is still largely a vision. Such smart grid visions, however, are not confined to Germany but are a global energy policy idea (e.g. in Denmarl and the USA) [61, 62].

storage, users and the grid itself using state-of-the-art information technology" ([64], p. 19). The vision of the smart grid positioned as a future solution to the upcoming problems is a reaction to the challenges emerging by the need to control and regulate a more and more decentralised and dispersed energy system. It addresses the increase in diversity of energy production and consumption, the volatility of renewable energies and the need for uninterrupted supply of energy. The smart grid promises to automate the energy system with the help of information and communication technologies and thus to create a new adaptive and self-organising energy system. In contrast to the old existing centrally controlled one-way system, which transports energy from particular sites of production to particular sites of consumption, the goal of the smart grid is to enable two-way flows of energy and information with sites of production and consumption changing in a decentralised system.[12] These changes can be induced by natural conditions (e.g. sunshine) or changing demand or production of energy.

In the corresponding discourses, it becomes clear that the realisation and implementation of smart grids would imply a wide variety of changes in the attached socio-technical arrangements, whose prerequisites and results are not clear today. This is why in recent years numerous pilot projects and field experiments have been initiated and conducted in Germany and the EU to test and develop smart grid designs [69].[13] The smart grid in these experiments is actually linked to many different ideas and experimental designs of smart grids [71, 72]. One of the most prominent and regionally distributed field experiments with different smart grid designs in Germany was the "E-Energy" programme. E-Energy was a consortium that tested the implementation of smart grid designs in different pilot projects in six regions of Germany, always using a different experimental design [57, 58].[14] This means that, in the different projects, the abstract and general smart grid vision become more specific through practical experimental designs.[15] Beyond the general idea of making the electricity grid smart and increasing its automation, many different ways of how to practically work on this vision were tested in the different smart grid experiments. Many of them were and are still in the making (e.g. with or without smart meters in private households, with or without electric vehicles as energy storage, see [58, 73]).

One of the most important insights gained from the discussions and experience from field experiments is that the implementation of the principles depicted in smart grid visions in the energy system would imply much more than new technical designs. Technical design is not a huge challenge (e.g. [58]). But the realisation of the vision would imply far-reaching and multi-dimensional transformations not only of technologies but also and first of all concerning the actors, knowledge flows, modes of governance and much more. The key finding is that the whole socio-technical arrangement of the electricity sector has to change. It is becoming increasingly obvious that the social changes envisioned, such as the shift from consumers to prosumers, inventions of new forms of electricity markets, novel business models and sustainable everyday practices, would involve massive changes in everyday routines (see also the emphasis on the "social factor" in [69], p. 11).

In the section "Visions as socio-epistemic practices", we specified four characteristics of visions working as socio-epistemic practices which are indispensable for the production of knowledge and practices of social reordering. These practical functions of visions are documented in reports on results and evaluations of experts involved in field experiments with smart grids. The documents and statements of experts show how the visions produce knowledge about options of socio-technical changes. Therefore, these visions open up the space of possibilities for new social arrangements to be tested in the experiments. The statements of experts from the

[12] Yet, they shall be simulated and controlled with algorithms that keep the system in balance and energy available, e.g. by "intelligently" telling certain system elements to consume less energy if there is less available. From this perspective, the smart grid vision builds upon such ideas as networking, ubiquitous computing and artificial intelligence and it envisions a thorough coupling of energy and information flows (see also [68]).

[13] By the mid-2000s, the vision had entered US and EU policies, and first smart grid research and experimentation projects were launched across the world. In the EU, more than 450 smart grid projects with different smart grid designs have been started since 2002, with a significant increase since 2009 [69, 70].

[14] The "E-Energy" project ran from 2007 to 2013 and was a federally funded R&D project involving industry, research and municipalities [58].

[15] See, for example, the huge variety of smart grid prototypes realised in the different regional pilot projects of "E-Energy" [58].

electricity sector in Germany (e.g. from power supply companies, local utility companies, industry associations, environmental associations, consumer protection associations, technology companies and scientific institutions) identify or imagine networks between very heterogeneous elements—discourses, artefacts, institutions, practices, etc.—that are affected by the changes or need to change.[16] These imagined networks are structured by temporal heterogeneity; there are always relations between "old", "new" and "not yet" implemented elements. The old elements are the ones that have been in the "energy system" for decades and have become routine and almost taken for granted in the eyes of the experts. Here, the experts think, for example, of the big energy suppliers with their fossil and nuclear power stations, routines of consumption established in the twentieth century, the structure of power grids, governance agencies, municipal utilities, certain forms of research and development and so on. The new ones are the elements that have recently entered the system. These elements are seen as catalysing drivers of change, bringing new patterns with them. Most significant here are renewable energies. They are accompanied by novel laws (e.g. the German Renewable Energy Sources Act), prosumers who produce and consume energy, field experiments and parliamentary decisions on the energy transition. Finally, the experts identify elements that do not yet exist in the system but are being imagined or experimented with in confined settings. These are mainly smart grid technologies, including their use and their respective governance and regulation. Other not yet existing elements which may be elements of future smart grids and were mentioned by the experts are, for example, electric vehicles, new service providers and new business models. As stated by different experts, the central challenge of the experiments was to test and learn how to connect old, new and not yet existing elements in a way that allows producing knowledge about feasible or required new technical combinations, new actor relations, new regulations, etc. The visions of smart grids played a crucial role in the experimental knowledge production. In the practical testing of new combinations of old, new and not yet established elements, the visions of smart grids in the first place served as interfaces between existing and not yet existing elements.

This shows how the visions can serve as an *interface* between the present and the future, allowing to create and conduct experiments. Since this interface can reveal specific needs for experimentation, the visions can serve as hypotheses of experiments. Furthermore, as we will explain in the following, the visions enable negotiations between the actors involved as a *medium of communication*. The visions allow the identification of *coordination* issues between the experimenting actors involved in the respective experiment and between different smart grid experiments. Also, the *normative force* of the visions becomes visible, especially in the individual evaluation of experiments by the experts. In the case of visions as socio-epistemic practices in smart grid experiments, we see how the four functions relate to each other and work together.

We will illustrate this by an example. In a description of the key findings from experiments with smart grid technology in a smart grid pilot project, given by an research and development (R&D) manager of one of Germany's four major energy suppliers, the following interrelation is stated:

The main insight was that we basically have the technical components, but that we face limits of profitability. A main barrier is the lack of a legal framework […] The first surprise was how difficult it was to make customers participate. We had to explain endlessly what we want to do to inform customers why we wanted them in the field test. For us, the system and the related changes were relatively clear, it's obviously not clear to the customer out there. Even business customers have not understood it until now. Well, the topic of flexibility, that's a way of thinking that is not there at all. […] Those who participated were actively engaged, they actually showed flexibility ([74], pp. 1–2, 24–25).

The experiments showed him that the tested technologies worked in most of the envisioned combinations of smart grid elements and designs—but only if seen separated from their social embedding. Thus, his main finding from the experimental test of the smart grid vision in practice was that the tested technology faced economic and social constraints, raising the question of regulation and legal frameworks and the whole socio-technical field of routines of consumption, market prices, existing technologies, values and knowledge of customers. The testing of the visions in experimental practice broadened the scope of the socio-technical constellation required for realising the aims of the envisioned changes. In this sense, the experiments with combinations of certain new and not yet established technical elements, enabled by the temporal *interface*

[16] These findings are mainly based on our expert interviews; see footnote 10.

of the vision, produced *needs* for other new combinations—but more on the social than on the technical level.

According to the R&D manager, another important finding was that the relation of himself (as one of the organisers of the experiment and a representative of an old "element" in the system) to the customers was peculiar as well. Customers first had to be convinced to participate in the field tests. They had to learn about the smart grid ideas and the relevance of testing them, which caused the supplier to identify the issue of communication as central to the pilot projects that depend on "real" households. Here, the importance of the vision as a *medium for communication* of needs in order to experiment in new ways becomes evident.

These insights together with his knowledge gained from the observed experimental rearrangements point to a change in positions of actors or in the way of addressing already established actors. While he still presents the old supplier in a traditional manner as the knowing and central actor to whom the "changes were relatively clear", he recognises openings in the configuration of actors, based on his observations. He recognises that the supplier himself is forced to learn and to experiment, to change his way of doing business and R&D. Now it is necessary to radically involve customers in the highly interactive arrangements of smart technologies, which follow a different paradigm than the one practised for decades. And there is a new role for former "customers". They now need to become a kind of co-experimenters who participate in the testing and creation of smart grid arrangements. This position, however, is also new to the customers, who were hard to involve and still displayed the old "way of thinking". There were, however, people willing to play the role of co-experimenters and who "actively" participated and "showed flexibility" in their consumption of energy. The flexibility of (in this case only a few) actors is pointed out as an important need and a general imperative for the opening and changing of habits and routines of consumption and should possibly include all actors of the energy system. Here, we see the *normative force* of visions at work. We can say that the application of the visions in experimental practice indicates that there is a fundamental demand for flexible co-experimentation between the actors as a new mode of enabling a smart grid-controlled energy system. The normative force of the visions emerges in the practices of the experiments. The experiments produce evidence for the feasibility of the visionary promises. The smart grid is positioned as being the best solution for the integration of renewables without a loss of control. The vision applied and proven in the experiments produced evidence that acting in a flexible and experimental manner is a social behaviour that fits best to smart grid technology.

The reach of this normative settlement also becomes clear in the quoted statements addressing the required changes in governance and regulation constellations. While there are still issues of classical regulation which are not conducive to profitable smart grid arrangements—a deficit of the old constellation of governance—,there is a completely new dimension of governing the customers in their role as co-experimenters. Communication, convincing through argument and other supportive ways of thinking are new tasks of actors used to old forms of top-down government. Furthermore, the statement of the manager demonstrates the increasing power of the formerly passive customers in the active governance of smart grid experiments and, therefore, also in the smart grid practices in the future. Here, we also see how the visions enable new *coordination* modes, for now limited to the experiments, but position them normatively as being the ideal and only adequate mode of governance and individual behaviour in the future. This governance of the collective and the self under the condition of a decentralised and smart grid-based energy system is emphasised as being the best form of organising the future energy system. As mentioned above, the normative force of the vision, emerging in the experimental practices, establishes the imperative for all actors to become and stay experimental, risky and flexible.

Such expert statements show that the experiments created a shared insight into the necessity of new constellations of actor positions, power and knowledge production in the whole system. The experts see a possibility of this socio-technical change in various rearrangements that support experimentation and heterogeneous experimental practices and help reorganise existing structures towards "smartness". The experts interpret the changes and experimental demands as a situation of being in between a destabilised old constellation and an open, not yet existing constellation of the future. The smart grid visions and their implementation in prototypical designs of smart grids can be seen as translators or interfaces between the present and the future. Through this function, smart grid visions can become hypotheses of the experiments. They designate specific experimental demands in relation to anticipated futures, which are communicated by the medium of smart grid visions. The smart grid vision enables communication amongst the actors of the experiments, who, however, define this vision, its implications and demands differently depending on their particular perspective. The different demands coordinate and motivate experimental practices without a central coordinating agency (as traditional measure of governance and regulation) since there is a shared and unquestionable consensus of the necessity for experimentation—in order to enable the smart grid for the new energy system. By positioning the smart grid as the best solution to achieve the aims and to manage the challenges of the energy transition, the vision develops its normative force, which motivates and urges all actors to change behaviour and governance in order to reach the aims and cope with the challenges. By experimentally proving the smart grid vision to be a solution to the fear of a loss of control in the energy system caused by its decentralisation and the volatility of renewables, almost unquestionable evidence for this solution is produced. This excludes other potential solutions to managing the volatility of renewables and the decentralisation of energy supply and consumption. But potentially it does not exclude any actors, provided that they are willing to change their tasks, roles and interactions in the networks of the energy sector.

Comparison and Discussion

We have argued for an integration of the analysis of visions as socio-epistemic practices in the assessment of the societal role and implications of new and emerging technologies and also of ongoing and open-ended transformations of socio-technical systems. The consideration of the practical role of visions in processes of changing socio-technical constellations is crucial for TA because of its role in political advice. However, this kind of analysis can be fruitful also for other, more theoretical reflections on socio-technical futures, since it offers a view on the empirical and material effects of change in knowledge and in practices of projected societal changes which could be caused by an emerging innovation process. We have shown that visions are not just imaginaries or narratives created or used by actors but that they arise in the making through the four main functions indicated before. We do not exclude that other functions could be found, in particular from the analysis of other case studies, inasmuch as we think that the concept of visions as socio-epistemic practices offers a fruitful heuristics for empirical research.

In order to demonstrate the strength of an approach which considers visions as socio-epistemic practices, we have analysed two rather different cases. We have shown how discursive practices and practical activities around IVM converge in the idea that this innovation is the best solution for a sustainable future of meat. IVM has developed as an idea of producing meat without using animals, bypassing all the negative impacts and ethical problems of current meat production and consumption. The normative appeal of IVM is the strongest characteristic of this vision, proposing itself as the best solution for the future of meat because virtually everybody with different interests and ethical stances concerning (traditional) meat can join it. Being an innovation at an early stage, it positions itself as the interface between the present and the future in food production. This vision is so large and comprehensive that it is capable of mobilising different forces in society and is thus a reference point for different interests. Due to this coordinating function, the potential of serving the interests of different social groups and its strong ethical appeal, the vision of IVM is expected to seriously enter the arena of sustainability discourses and to be considered as an option for reconfiguring future food politics. Indeed, in the last couple of years, IVM has attracted significant attention from the scientific community and, at least to some extent, from politicians too.

The vision of a future smart grid which should replace the traditional electricity grid in the energy system is a very powerful one. It guarantees to solve all the problems of losing control over a more and more decentralised, flexible, dispersed and regionally distributed energy generation and consumption. According to various energy system and other societal actors, this is an unavoidable effect of the massive integration of renewable energies into the system. The smart grid vision promises a secure and at the same time sustainable energy supply—by replacing the centralised control of the big energy suppliers and politics through one technological solution, the smart grid. The vision of the smart grid is dynamic enough to be specified in relation to the particular conditions and needs of all regions and all actors involved. Several field experiments are currently testing adequate new socio-technical arrangements between the relevant actors and smart grid components. In these experimental practices, the overall vision specified for the exact needs of the experiments acts as an interface between present and potential future arrangements to create the experimental designs. The vision integrates the different interests of the participating actors by serving as a shared communication medium and thus coordinates the experiments. In these experimental settings, the smart grid vision is irreplaceable for the production of knowledge on how to reorganise socio-technical arrangements in a way that they could fulfil the aims of the energy transition. But the strongest appeal of the smart grid vision might be the fact that—as shown by the experiments—it hardly ever excludes old actors and encourages the participation of many new ones, if they are willing to modify their roles. Probably because of this, the smart grid is an almost unrivalled vision. However, the overall normative imperative of the vision is to stay always flexible and open for new experimental changes.

The two case studies provided insights into existing constellations between technical and social actor networks, political interests, governance issues and other elements relevant to the processes of change. TA needs detailed and comprehensive knowledge on the socio-technical interplay in ongoing changes if it wants to assess the situation and be able to give advice about the potential impacts of IVM or smart grids and their respective management. This corresponds with the challenges of TA to assess impacts in an unforeseeable future when present constellations and their dynamics of change are the only starting point. However, this perspective is not only of interest and value for TA but is also important for STS confronted with current phenomena of emerging technologies. Our focus on visions as socio-epistemic practices enriches STS models of change (e.g. the translation model of ANT or the innovation model of transition theory) by providing an analytical view on visions in concrete and ongoing practices of rearranging the relevant socio-technical constellations. We hope to offer an analytical prototype which can then also be applied to other cases and is of interest and value for both, TA and STS. In this approach, insights are produced by means of a focus on visions at work, regarding the enabling constellations for desired innovations but also undesired impacts. Such knowledge is crucial for real-time assessments.

Considering visions as being constitutive, socio-epistemic practices permits to grasp elements of diffuse actions and coordination which may be missed by other perspectives which interpret these practices as activities of visioneering, considering the ideal and practical role of particular actors in the construction of imaginaries about an innovation. In contrast, our view on visions as socio-epistemic practices looks at the collective dimension of such imaginaries and focuses on their practical relevance in transforming constellations rather than on reconstructions of the roles of actors creating the visions, and their history. Our approach can be seen as a contribution to illustrate how collective visioneering is expanding its boundaries from definite actor groups to diverse practices far away from the intentions of the original visioneers. At the same time, it allows to analyse how collective visioneering emerges in its entangled, contingent, open-ended "nature" from these practices.[17] In summary, we can state that our analysis is both, a critical deconstruction of too enthusiastic beliefs in visioneering and a sober reconstruction of how visioneering works.

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[17] For reflections on the ambivalent relation between TA and visioneering, and on TA as a visioneering (assessment) actor, see [75].

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