Energy Days 2017

Can you feel the energy?

The 'Sensory Governance'

of energy technologies and systems

Helmholtz Centre for Environmental Research – UFZ

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Workshop documentation

Table of content

1. Introduction

This workshop documentation reproduces issues, questions and insights of the interdisciplinary workshop 'Can you feel the energy? The "Sensory Governance" of energy technologies and systems'. The three-hour event took place on March 16 2017 at the Helmholtz Centre for Environmental Research –UFZ as part of the 2017 edition of the UFZ Energy Days.

As the title suggests, the workshop focused on the *sensory dimension* of energy-related environments with the aim to explore how 'sensible issues' were addressed or governed. By 'sensible issues' we mean aspects and questions that are both problematic and perceptible with sensors and/or our senses. In the workshop, we thus assembled empirical evidence on perception-related problems and sensory annoyances that occur in the course of energy transitions as an issue of public debate, expert controversy and regulatory efforts. In particular, we explored controversies over the smell of biomass plants, the noise or visual impression of wind power plants and the imperceptible side effects of geothermal energy. On the other hand, we were interested in understanding how such issues are tackled or solved through 'sensory governance' as we call it. As described below, 'sensory governance' refers to practices that address the perceptibility of socio-technical transformations in our environment and tackle 'sensible issues'.

The focus on 'sensible issues' and their governance gains relevance in the context of current energy transitions. The switch to renewable energies coincides with a decentralisation of energy production and new land uses. The individual and shared perceptions of these new environments can have political, economic and socio-cultural implications as the empirical examples of our workshop suggest.

During our three-hour-long session we had an introductory input of the workshop idea and aims, followed by four presentations on different energetic examples and time for our joint discussion that was structured around our guiding questions. This documentation first introduces and explains our conceptual focus, then summarises the empirical evidence and insights we gained from four workshop presentations and workshop discussion and concludes with an outlook on open and further-leading question. We have taken the liberty to add ideas and aspects that were not raised during the session. These remarks come from a sociological perspective and are inspired by studies on Science, Technology and Society (STS). They are meant as food for thought and an invitation to continue the discussion on 'sensible issues' and 'sensory governance'.

2. Background: 'Infrastructural inversion' of 'invisible infrastructures'

'As we learn to rely on electricity for work, our practices and language change, we are "plugged in" and our daily rhythms shift. The nature of scientific and aesthetic problems shift as well.' (Star and Ruhleder 1996: 5).

Can we feel the energy, the sizzling of the high-voltage energy grid or the electricity we use? We definitely could, but it is more convenient to be unaware of the almost ubiquitous presence of energy supply infrastructures. It is also quite easy since the work of planning, building and maintaining energy technologies and systems has long been delegated to experts and taken for granted. Sociologists speak in this context of 'invisible infrastructures', which are so taken-for-granted that they are easily overlooked and only become visible when they fail. "Good infrastructures are difficult to find", write Geoffrey Bowker and Susan Leigh Star (1999).

Infrastructures can thus be described as 'something that is built and maintained, and which then sinks into an invisible background. It is something that is just there, ready-to-hand, completely transparent.' (Star and Ruhleder 1996: 4). The sociologist Leigh Star and computer scientists Karen Ruhleder therefore suggest that it is more useful and accurate to focus on situated socio-technical interactions rather than functionality: '…we ask, when— not what— is an infrastructure. Analytically, infrastructure appears only as a relational property, not as a thing stripped of use' (Star and Ruhleder 1996: 4).

In methodological terms, this change in perspective can be described as 'infrastructural inversion' (Bowker 1994). It is 'a struggle against the tendency of infrastructure to disappear (except when breaking down). It means learning to look closely at technologies and arrangements that, by design and by habit, tend to fade into the woodwork (sometimes literally!)' (Bowker and Star 1999: 34). However, this 'powerful figure-ground gestalt shift' (Star and Ruhleder 1996: 5) is does not refer to aesthetical questions and the reference to 'invisible infrastructures' means that they are taken-for-granted. As Masato Fukushima (forthcoming) points out, the term 'invisible' is almost synonymous with non-attention.

Our focus on 'sensible issues' and their 'sensory governance' is in line with the *relational inverted* perspective. Yet, it takes the aesthetic metaphor of in/visibility literal. In contrast, 'sensory issues' and 'sensory governance' *literally* refer to the visual perceptibility or imperceptibility of energy technologies and systems, their acoustic, haptic and olfactory qualities as well as the sensing techniques that are used to objectify and evaluate individual sensory experiences.

3. From ‘invisible infrastructures’ to ‘sensory governance’

The metaphorical ‘invisibility’ of energy technologies and systems has very often a material sensory dimension. Infrastructures are buried under ground, built in the periphery and removed from view behind walls. As long as experts maintain and operate our energy production and supply, energy users perceive rather little of the energy-related technologies and systems. This black-boxing is intentional and also a great achievement of industrialised societies.

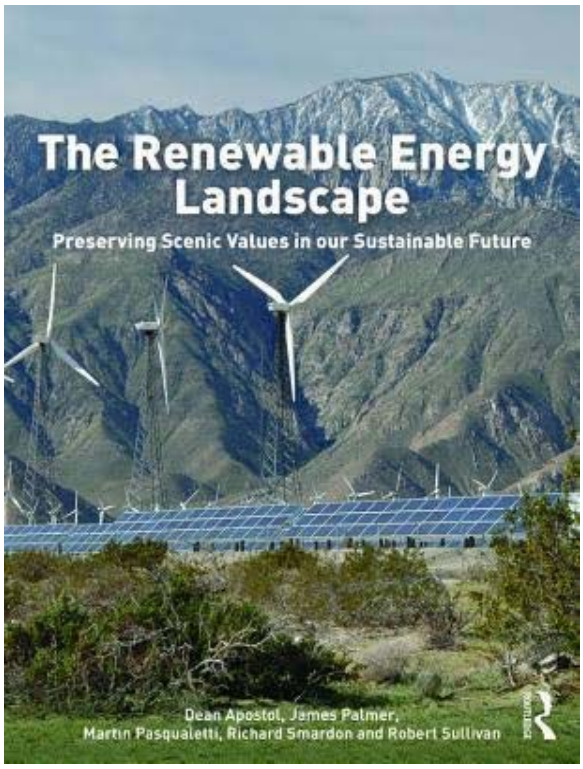

Figure 1: Book by Apostol, Palmer et al. published by Routledge 2016)

Yet, the situation can change dramatically when new technologies are implemented and familiar routines and living environments are changed like in the context of the German *Energiewende*. All of a sudden producing and using energy ‘feels’ differently and the sensory qualities of energy technologies and systems can become an important issue. People *perceive* the transition of their back yards and living environments into a ‘renewable energy landscape’ (see book cover Apostol, Palmer et al. 2016) and complain about sensory annoyances. Complaints and protests can slow down the progress of infrastructural projects.

In other cases, the *imperceptibility* of potential environmental impacts can be an issue in expert debates and risk assessments and hamper sustainable technological development and innovation, especially when adequate sensing methods or sensors are lacking or costly. Last but not least, individual perceptions can clash with measurable or modelled impacts and raise issues of scientific representation and evidence production.

Despite their variety, ‘sensible issues’ have in common that they draw attention to the different ways in which people experience and evaluate changes in their environments. Analytically speaking, they are an indicator for changed relations *between* individual sensory *perception*, socio-technical *environments* and sensing *techniques* (see Figure 2) and make changes in sensory infrastructural relations observable. This form of ‘infrastructural inversion’ is all but trivial as sensory perception is deeply entangled with sense-making, beliefs and expectations as we will see in more detail below.

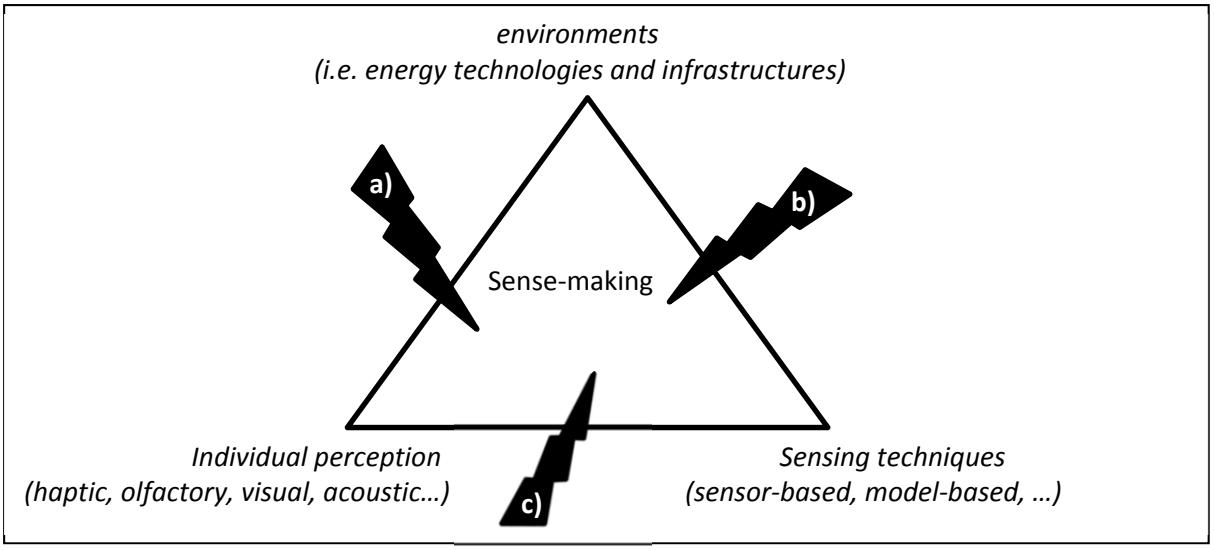

Figure 2: Three potentially problematic relations

In the workshop, we considered it as an empirical question to identify 'sensible issues' in energy-related contexts. We were particularly interested in *what is perceptible* to whom, where, when and how, and *what counts as sensible evidence*. The underlying assumption was that individuals and groups *perceive* and experience their socio-technical environments differently, objectify or evaluate their experiences by different means (including senses or sensing techniques) and hence make different sense of their changing environment. In the next step, we were interested in whether and how problematic relations are fixed or stabilised through 'sensory governance'. We focused on three relations in particular (see Figure 2):

a) Problematic relations between individual perception and socio-technical environments
b) Problematic relations between sociotechnical environments and sensing techniques
c) Problematic relations between individual perception and/or sensing techniques

Sensory governance

By 'sensory governance' we mean all sorts of practices that are designed to prevent, settle or decide debates and controversies over 'sensible issues'. The notion of 'sensory governance' is no established concept but a term we propose for analysing the sensory dimension of infrastructural politics. By focusing on 'sensible issues' and their governance we hope to better understand how our senses and sensing techniques are an impediment or driver of energy transitions. Practices of 'sensory governance' include infrastructural designs, the use of sensing techniques for evidence production and the definition of thresholds for 'sensible issues' like noise, smells or temperature changes. In the context of energy transitions, such practices matter in at least three respects.

- **Project planning:** Tackling 'sensible issues' like controversies over sensory annoyances or expert debates over imperceptible evidence can slow down or speed up planning processes (cf. Pohl, Hübner et al. 2012).
- **Innovation:** Managing the 'sensible issues' around emerging energy technologies and systems can contribute to their smooth deployment and stabilisation (cf. Hargadon and Douglas 2001).
- **Legitimisation:** Making new, costly infrastructural transitions noticeable can be important for generating public participation, acceptance and public legitimacy.

We consider these practices as *political* as they involve deliberation, decision-making and power play. They are also political in a performative sense as they create

- **Communities** of people that share specific sensory relationships with their environment and make common sense based on shared experiences, knowledge or ignorance (e.g. blindness).
- **Diverging views** that can divide those who perceive 'sensible issues' and those who don't.
- **Inequalities** between those who can shape the perceptibility of infrastructures via sensory governance and those who cannot.
- **Categories and standards** that define what is perceptible and acceptable and what is not.

As the following selective summary shows, the workshop presentations focused on a variety of 'sensible issues'. Questions of 'sensory governance'—what, who, how, where and when—will be briefly touched in the outlook and conclusion.

4. Smelly biomass, blinking wind power and imperceptible geothermal energy

The workshop presentations assembled evidence and insights from different disciplinary perspectives and in different empirical fields such as biomass, wind power and geothermal energy and highlighted different problematic relations (Box 1). Stefan Majer, Johannes Pohl and Gundula Hübner focused on cases where the perceptibility of new socio-technical environments was an issue, i.e. the relationship between people's individual sensory perceptions and their environment. Thomas Vienken discussed problematic relations between sensing techniques and subsurface socio-technical environments that are otherwise imperceptible. Jochen Wendel and Roman Zorn presented examples of participatory monitoring that highlighted the changing relation between individual senses and sensing techniques (see Box "presenters and presentations").

Box 1: Presenters and presentations

Stefan Majer, Deutsches Biomasseforschungszentrum – DBFZ, Leipzig: When energy smells funny. The sensual aspect of Bioenergy

Johannes Pohl & Gundula Hübner, Martin-Luther-Universität Halle-Wittenberg**:** Stress effects of wind turbine noise: The role of psychological factors

Thomas Vienken, Helmholtz-Zentrum für Umweltforschung – UFZ, Leipzig A matter of degrees - prediction, monitoring, and evaluation of subsurface temperatures for the sustainable use of shallow geothermal energy

Jochen Wendel & Roman Zorn, EIFER – European Institute for Energy Research: Participatory monitoring for energetic and environmental phenomena

A list of questions had been sent to the presenters beforehand (Box 2). The question are now used in a slightly modified version to structure the following recollection of the four presentations.

General questions

1) **What are 'sensible issues'** in energy-related contexts?
2) **Who is involved**, in which role and with **which senses, sensors and methods**?
3) **What effects or risks** are attributed to 'sensible issues'?
4) Is there **disagreement over the perceptibility or evidence** of 'sensible issues'?

1) What are the 'sensible issues' in energy-related contexts?

The first two presentations by Stefan Majer and Johannes Pohl focused on issues related to the sensory perception of energy infrastructures, the presentations by Thomas Vienken, Jochen Wendel and Roman Zorn on sensing issues (Table 1).

What are the 'sensible issues?	Stefan Majer	Johannes Pohl & (Gundula Hübner)	Thomas Vienken	Jochen Wendel & Roman Zorn
Problematic relation between individual perception and socio-technical environments				
Perceptible energy is problematic	Gas users feel that biogas smells badly or differently.			
Perceptible energy production is problematic	Local concerns about the smell of biomass plants and transport noise.	The sound of wind power plants can cause individual stress.		
Problematic relation between socio-technical environments and sensing techniques				
Imperceptible energy is problematic			Reliable ground-water temperature montoring is associated with large efforts	
Imperceptible energy production is problematic			Heat pump systems are often black-boxes for energy 'prosumers'	Citizens monitor seismic activity with cheap sensors.
Problematic relation between individual perception and/or sensing techniques				
Individual and technological sensing produces incongruent data	Gas users smell a difference between biogas and natural gas which cannot be measured.	Expectations can influence effects of (infra)sound.	Sensor-based data of subsurface effects vs. model-based simulations	Participatory sensing adds to/challenges conventional sensing data

Table 1: 'Sensible issues' and problematic relations in energy-related socio-technical contexts

Stefan Majer offered insights into the perceptibility of bioenergy production. The DBFZ team is actively involved in engineering and planning processes and focuses on life-cycle analysis. However, they also find that sensory nuisances can play an important role regarding the public acceptance of new biomass plants. Bad smells are thereby often the most obvious negative argument, but the noise

of biomass transports and the visual transformation of agricultural areas into mono-cultural crop fields can also be an issue.

In terms of olfactory nuisances, biogas can be considered as quite unique in the renewable energy landscape.[1] Smells are strong and also change with the wind direction or depending on the specific content of the biomass silos so that the nose might not adapt, i.e. get use, to the smell of neighbouring bioenergy production site.[2] Moreover, what people smell is affected by what they know. In a biomass project on a French dairy cow farm, a pipeline supplied a neighbouring village with bio-methane. When local people later realized that their gas came from the nearby farm they reported that they could smell or taste the dairy cows or manure when using the gas in their kitchen. As Stefan Majer pointed out, the chemical composition of the gas did not differ from the gas they had used before, which raises the question of how sensory perception relates to scientific evidence production. In this respect, psychological research offers explanations.

Johannes Pohl gave an overview over psychological studies on stress effects from noise perception in the wind energy context and presented their own research (with Gundula Hübner). The point of departure is that objective characteristics of sensory sources of stress (e. g. sound pressure level) cannot fully account for individual annoyance—74 per cent of the annoyance variance cannot be explained. He further showed that the individual sensory perception of 'sensible issues' cannot be disentangled from what people expect and know about infrastructural projects. Negative expectations of wind turbines lead to more negative experiences.

For instance, researchers found 'nocebo' effects when testing the stress effects from infrasound (Crichton, Dodd et al. 2014). Two groups of test persons were told that they would hear infrasound but only one group was actually exposed to it. Nevertheless, both groups reported increased stress levels. Moreover, negative information about the effects of noise can affect its perception. Other studies found that negative attitudes towards the local wind farm before starting operation can lead to greater stress effects after starting operation than neutral or positive attitudes (Jalali et al. 2016a, b). Chapman, George et al. (2013) showed that in regions with opponent groups there is marked increase in number of complaints. Stress effects caused by noise are also less pronounced when energy transition projects are perceived as just and fair (Pohl, Gabriel et al. 2014).

Thomas Vienken focused on 'sensible issues' that regard experts and their sensing techniques. In shallow geothermal projects ground water temperature is a 'sensible issue' because it is difficult to reliably monitor and model but matters in the planning process and beyond. Ground water temperature changes are relevant for energetic and for environmental reasons. The warmer the water, the more efficient is the geothermal systems. But energy extraction and seasonal heat storage impact groundwater temperatures. Induced temperature changes must stay within legally binding limits in order to safeguard good ground water quality. In the planning phase, project developers need to provide the respective data that show that their systems will not significantly change the ground water temperature.

[1] Stefan Majer invited the workshop participants to visit the DBFZ test sites next to the UFZ for a smell test.
[2] In addition to production sites, bioenergy can itself become a curious 'sensible issue' as in the case of the large scale biofuel use (e.g. as E10), which became problematic due to further-reaching environmental considerations (e.g. monocultures of crops, etc.). Thus, E10 raised public scepticism and some users of the fuel argued they could feel that their car engine ran differently.

As Thomas Vienken explained, temperature changes are usually simulated on the basis of plausible models that account for geological and hydrological factors. But real-world conditions and actual energy consumption might diverge from simulated heat exchanges. In a scientific UFZ project they therefore also *measured* the temperature subsurface with sensors in purpose-built wells.[3] Yet, measuring subsurface is a challenging task since the choice of measuring points is not only based on scientific criteria but restricted by administrative constraints. The UFZ results showed that the location of wells can have a significant impact on the measured temperature and hence raise 'sensible issues' with regard to modelled simulations.

Jochen Wendel and Roman Zorn work on cases where the *im*perceptibility of new infrastructures such as geothermal energy systems becomes an issue of public concern. Such 'sensible issues' can arise when people fear that they might be affected by energy projects but lack the instruments to verify or dismiss their fears. Jochen Wendel and Roman Zorn thus analyse and develop sensory means for *participatory sensing* that offer laypersons the means to produce evidence, for instance to measure the air quality. Another example was a sensor device that allows laypersons to monitor seismic activities caused by deep geothermal energy in order to detect whether the new renewable energy production in their region actually causes cracks in their houses. The devise uses joystick technology for measuring vibrations in different axes and is cheap enough for private use.

Similar examples of mobile, participatory data collections can be found in the context of health and urban planning. Jochen Wendel's referred to an 'air quality app', which was one of the earliest crowd sourced apps.[4] Another application for collective air quality modelling makes use of mobile asthma monitoring devices to collect and aggregate data that shows where asthma inhalers are used. Thus, local clusters of particularly frequent attacks might be detected and be an indicator for air quality problems in a specific place (Aldridge 2011, Comstock 2013). More detailed spatial information is also the key advantage of a project at the Karlsruhe Institute for Technology (KIT), where the trams were equipped with sensors to monitor the air quality across the wide-reaching public transport network. Another participatory sensing project in New York produces more fine-grained information on heat islands.[5]

2) Who is involved and uses which senses, sensors and methods?

As we have seen, stakeholders involved in 'sensible issues' do not use the same sensing techniques. The presentations showed that their local and institutional settings vary considerably. Different stakeholders can draw on different resources and have different audiences when they bring sensible issues to the fore. Even the 'use' of one's nose, ears and eyes can be learnt and improved through constant training and professional practice. As sociological research suggests (Hennion 2007), people who train their senses cannot only perceive more, but also make different sense and develop specific attachments with their environment. We were therefore interested in the key actors, their sensing practices and their sensory relationships.

[3] Such measured data are particularly relevant in areas where shallow geothermal systems are used increasingly on a large scale or in close vicinity and might thus interfere with each other.
[4] https://airqualityegg.wickeddevice.com/, last access 2017-07-20.
[5] Urban heat islands are measured with a spatial accuracy of 1 square kilometer. Yet, on this scale temperature differences that can occur between an urban park and a neighbouring street with high-rise buildings are completely leveled out and ignored although they can have health effects on the local population.

When looking at the stakeholder in energy-related projects, the most obvious distinction is the one between energy *producers* who work with energy technologies and energy *users* who are used to having rather little contact with socio-technical systems.[6] Yet, this distinction is no longer clear-cut.

The workshop presentations showed quite clearly that actor constellations are changing in the course of the current German energy transition. While fossil and nuclear energy production takes place in the periphery, renewable energy production and consumption are moving closer together. As Stefan Majer pointed out, biomass plants are built in the immediate surroundings of feedstock. Farmers not only know how to operate their plants but also use their own biogas and supply their neighbours. They can all smell the energy production. Wind power turbines have entered populated areas where energy users can hear their sound and see their shadows or blinking lights (Pohl, Hübner et al. 2012). 'Prosumers' of shallow geothermal energy have installed the respective systems in their houses (Bleicher and Groß 2015).[7] Deep geothermal energy has come close enough to raise concerns about seismic activity and cracking and damaged house walls (cf. presentation by Jochen Wendel and Roman Zorn).

The availability and use of new sensing technologies is another factor that can change actor constellations, as outlined by Jochen Wendel and Roman Zorn. Participatory sensing—or citizen sensing (Gabrys 2016)—puts individuals in the position to engage with their environment in new and different sensory ways. Laypersons can become knowledgeable 'amateurs' (Hennion 2007, Schulte-Römer 2014). Thus, citizen sensing projects acknowledge and address the asymmetric distribution of means for sensory evidence production. They challenge the common scenario where only experts have the technical means to model or measure sensory facts and are also better trained to perceive 'sensible issues' with their own senses.

Last but not least, it is important to note that science plays an important role for the discovery, articulation and mediation of controversies over 'sensible issues'. In this sense, all presenters also actively engage in their different disciplinary roles in the 'sensory governance' of im/perceptible infrastructures.

3) What effects or risks are attributed to 'sensible issues'?

The presented cases and studies show that the evaluation of im/perceptible artefacts and environments cannot be disentangled from individual and shared expectations or from the practical purpose of sensing efforts. Moreover, the practices that turn feelings, impressions and imperceptible socio-technical artefacts into objectified, acceptable and presentable facts are also not neutral. For instance, sensor-based evidence is usually produced by experts that are well familiar with energy infrastructural planning or maintenance but do not necessarily share the perspective of those who have built their house or raise their children in the vicinity of emerging energy production sites.

Negative economic effects are the most obvious effects that affect different stakeholders in project and energy-specific ways. In the case of shallow geothermal energy, measuring temperature changes

[6] This corresponds with the notorious distinction between experts and laypersons which is problematic because it can be misleading as there are different forms of expertise. Cf. Collins, H., & Evans, R. (2008). *Rethinking expertise*. University of Chicago Press.

7 Nevertheless, their heat pumps protect them from the sensible issues of ground water temperature changes as described by Thomas Vienken. Black-boxed as these systems are, they do not offer them information on groundwater temperature.

in the subsurface has a direct financial impact on private energy producer-users. When ground water temperatures drop, the efficiency of geothermal energy systems is reduced. In places where neighbouring houses are equipped with geothermal energy pumps, energy producers that use ground water that has already passed their neighbours ground might have energetic and financial disadvantages.

Indirect negative economic effects are common in energy-related infrastructural projects and key arguments in controversies over sensory nuisances. House owners fear or actually find that the smell of nearby biomass plants, the close deep geothermal drilling or the noise of close-by wind turbines might diminish the value of their property. Project planners are negatively affected by public controversies over 'sensible issues'. Public protest can render infrastructural projects much more expensive than expected, due to the costs of conflict mediation and/or financial compensations.

What we did not explicitly discuss but what might be still worth considering is the question of whether economic rationales are proliferated or even induced by the use of financial instruments when it comes to engaging and compensating local stakeholders in energy projects. Economic willingness-to-pay surveys that test the public acceptance of infrastructural project point in that direction.

Negative health effects like stress or chronic diseases are another aspect in debates over straining exposures to noise or pollution. As Johannes Pohl's presentation showed, stress effects are multi-factorial phenomena, even if the affected individuals blame 'sensible issues' for their annoyance.[8] As discussed in the workshop, it might be worthwhile differentiating between individually perceived stress symptoms, which can be partly alleviated through fair planning processes and opportunities for political or economic participation, and potential long-term health of sensory nuisances. Just like people can believe that their perceive infrasound because they expect or know it is there, our sensory system might be exposed to stressors that are imperceptible and cannot be voiced because we do not know their effects and do not search our body for symptoms. The flipside of *misattribution*, as described by Johannes Pohl, might be *missing attribution* if exposure is imperceptible.

Positive effects are theoretically possible but were not discussed in the workshop as the focus was on problematic relationships.[9] Furthermore, the so-called 'cultural lag' (Ogburn 1957) might have particularly strong consequences for the sensory perception of new energy technologies and infrastructures. New technologies are first alien, unfamiliar and potentially disturbing, also to our senses. They feel differently for their users and transform the landscapes that we know. In addition to that, the metaphorical 'invisibility' of existing infrastructures can make it difficult to put the new developments into perspective. Thus, the sensory impression of corn fields, wind mills, solar panels and the smell of biomass are usually evaluated as such and where they are, without putting them into perspective or comparing them to the sensory appeal of pit mining, coal power plants and nuclear reactors elsewhere.

[8] The evaluation of stress effects can itself be a 'sensible issue'. As discussed in the workshop, long-term health effects of sensory annoyances are hard to detect. Evidence in this respect is often based on the evidence of statistical correlation in epidemiological studies since it is difficult to identify causal links between sensory stimulus and multi-factorial pathogenic effects.

[9] The sound or smell of renewable energy production might also be associated with positive ideas, e.g. the thought that a stinking biomass plant or noisy windmill is not only reducing our society's carbon footprint but also making money for its 'prosumers' (see p.10).

4) Is there disagreement over the perceptibility of 'sensible issues'?

The disagreement of what is perceptible and what is not was most present in Johannes Pohl's presentation on 'nocebo effects', as outlined above. The examples of wind turbine noise, but also the case of biomass smells show that scientific evidence and individual experience are not always congruent and thus draw attention to the potentially problematic relation between individual sensory perceptions and scientific sensing techniques. Individuals can hear noise and smell differences that are, scientifically speaking, inexistent.

Moreover, the examples of participatory sensing and measuring or modelling in the subsurface showed that 'sensible issues' that involve the sensing techniques are governed within the boundaries of administrative, legal and political institutions. Changing these institutions and their conventions of evidence production leads very likely to disagreement over the technologically mediated perceptibility of 'sensible issues'.

A problem that was addressed in the group discussion was the question of data quality and management in the context of participatory sensing. Since the calibration and measurement techniques differ from conventional modes of scientific evidence production, sensing technology can as well produce disagreement. In which situations is data from participatory sensing acceptable (insurance cases, planning processes, political deliberation…)? Who can decide which data counts and which does not? It was also pointed out that in cases of disagreement, mis/trust and in/transparency play an important role. Participatory sensing devices (mobile air pollution measurements) might be a good way to trial official data collection (e.g. municipal air pollution sensors) and challenge municipalities to make their choices more transparent.

5. Conclusion and a last note on 'sensory governance'

The workshop showed that energy infrastructures are no longer invisible in the context of sustainable energy transitions. The German *Energiewende* has brought energy technologies and systems next to or even into the homes of electricity and gas users and it smells, sounds and feels differently than former energy landscapes. Although the new feels not necessarily worse than coal or nuclear energy, its sensory perceptability can become an issue of public concern or even controversy. In this regard, the workshop discussion made it quite clear that individual sensory experiences of renewable energy are complex and entangled in people's broader understanding of the innovation process. For instance, if people feel that they have to suffer while others are making profit and consider a project or process as unfair, its noise and smell will disturb and stress them more. Psychological studies show accordingly that people with positive expectations feel less stressed if their environment is changing in perceivable ways. Such expectations can be positively affected through political participation, which seems most effective in early stages of project planning, or through financial compensation (as one participant remarked with a touch of irony: 'wind turbine noise will turn into music if the wind mill is making you money'). Yet, money might not be the only sensible response. Looking at infrastructural projects, we also find legal or building standards that are designed to tackle 'sensible issues' (minimum distances between houses and wind turbines, thresholds and directives for noise and light, etc.).

These attempts to prevent, settle, or decide debates over sensory nuisances can be considered as ‘sensory governance’. They *physically* remove to object of contestation. While financial incentives and local involvement works on the expectations and framings of people, thresholds, minimum distances or building measures work on the sensory dimension. Psychological findings can contribute to finding the most suitable solutions.

On the other hand, infrastructures can produce inequalities because they affect people physically or materially in imperceptible ways until the harm is done. Public scepticism or protest against nuclear technology or energy production in the subsurface might result from the creepy feeling that something imperceptible is going on that cannot be controlled. In this respect, the example of the participatory seismic sensing offers another good example of sensory governance.

This raises the question of whether the strategic policy-oriented funding of citizen science projects might not also be considered as a form of sensory governance. New sensing technologies including mobile phone applications, drones and other sorts of sensors that are easily accessible and cheap to use have the potential to shift the locus of sensible data production and might thereby have an effect on individual perceptions and reactions to environmental changes and energy systems. They might contribute to objectifying sensory perceptions, but also to disentangling them from personal expectations and frustrations. It remains to be explored whether such effects can be proven empirically and how their effects should be evaluated with regard to participation and sustainable energy transitions.

To conclude, it seems that the governance of our sensory perception can transform or mediate conflicts, but also produces new conflict lines and inequalities between the affected parties and stakeholders. To be able to perceive transformations in the environment creates the basis for making sense of it. Thus, any technique that enhances our perception of our changing socio-technical environment offers a powerful means to produce evidence, make public claims, mediate ‘sensible issues’ and to govern or reflect on one’s own or others perceptions of too perceptible or imperceptible infrastructures. This workshop only offered a starting point for exploring such interventions and discussing the relations between perception, sensing techniques and socio-technical environments.

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7. Handout

Energy Days 2017, UFZ Leipzig

Workshop B2, March 16, UFZ - Kubus

“Can you feel the energy? The 'Sensory Governance' of energy technologies and systems”

Workshop Schedule

9h00 – 9h15: Welcome and workshop introduction

Nona Schulte-Römer, Alena Bleicher, Matthias Groß – all Department of Urban & Environmental Sociology, Helmholtz Centre for Environmental Research – UFZ,

9h15-10h55: Presentations (à 15 minutes + 10 minutes questions and discussion)

- **When energy smells funny. The sensual aspect of Bioenergy**, *Stefan Majer - Department of Bionergy Systems, German Research Center on Biomass DBFZ, Leipzig:*
- **Stress effects of wind turbine noise: The role of psychological factors**, *Johannes Pohl; Gundula Hübner - Psychology Department, Martin Luther University of Halle-Wittenberg, Halle (Saale):*
- **A matter of degrees - Prediction, monitoring, and evaluation of subsurface temperatures for the sustainable use of shallow geothermal energy,** *Thomas Vienken - Department of Monitoring and Exploration Technologies, Helmholtz Centre for Environmental Research - UFZ, Leipzig:*
- **Participatory monitoring for energetic and environmental phenomena**, *Jochen Wendel, Roman Zorn - Energy Planning and Geosimulation, European Institute for Energy Research (EIFER), Karlsruhe*

General questions regarding ‚Sensory Governance‘ and ‚sensible issues‘

- **What are the ‘sensible issues’** and how are senses and sensors part of controversies around energy-related infrastructures, practices and energy transitions?
- **What effects or risks** are attributed to sensible issues and what values are concerned?
- **Who is involved in controversies** and in which role? E.g. project planners, governmental agencies, investors, neighbours, local communities.
- **Who uses which senses, sensors and methods** to bring sensible issues forward and for which audiences or publics?
- **What is im/perceptible to whom? What is perceived as ‘normal’ by whom?** E.g. is there disagreement on the perceptibility of ‘sensible issues.’

Short Break

11h05 – 11h45: Group discussion

Group discussions

1. **Technology focus**: Biomass, geothermal, wind energy, etc.: Can we distinguish specific types of controversies over ‘sensible issues’?
2. **Focus on senses and sensors**: What means and methods of ‘Sensory Governance’ are used to make ‘sensible issues’ im/perceptible?
3. **Focus on actors**: Processes and approaches of ‘Sensory Governance’: Can we observe patterns in the mediation of sensory controversies?

11h45-12h00: Reporting back, wrap up and good bye