Democratic decision making and the role of (climate) science

Climate science cannot answer the question which impacts a climate policy can have on, say, economy, on energy supply, on social justice, or on public health. In particular, climate science is unable to assess the conditions for the EU-goal “of safe, secure, sustainable, and affordable energy”.

Climate science can, and has done so, provide the needed knowledge about the climatic consequences of a variety of paths of releasing climatically active gases into the atmosphere. If more of such gases is released, then the changes in climate are larger and the need for adaptation grows. Emissions and climate change are linked in almost linear manner: more CO2 means stronger temperature rise, less CO2 smaller temperature rise. It is not important, where the emission takes place on the globe; also the timing in the last decades of years of the missions are of secondary importance.

International climate policy has agreed in 2015 in Paris that climate change at the end of the present century should be limited to 2°, or even better 1.5°, and that after the year 2100 no further anthropogenic climate change should take place. This is a political goal and not the scientific goal. However, climate science can determine, if this goal can be reached by given measures.

The question of how to react to the presently ongoing climate change and to the prospect of additional future changes is to be answered politically; it is a decision related to values and preferences, but not a conclusion drawn by science. Science has contributed to this decision process by assessing the possible consequences of the variety of political choices.

I am a natural scientist, and a little bit a social scientist. In the following I will discuss a few issues, which may support the public discourse about dealing with possible future climate change. For doing so I have chosen mostly the verbal presentation, and not the standard of natural scientists with PowerPoint and diagrams. I will not refer to numbers, to specific mechanisms, to dynamical details, but about concepts and the process of public decision-making.

Allow me to begin with them kind of ***summary***; later I will add a bit more depth:

The most significant achievement of international climate research in the past 30 years has been the identification of an ongoing global warming, the statistical proof that causes external to the climate system are behind this change, and that the link between elevated greenhouse gas concentrations and warming is the only available physically consistent explanation for the warming at this time.

This result, which is sometimes named the detection of non-natural change and the attribution to greenhouse gases as drivers, has initiated a new dynamic in international policies, named "***climate protection***", which is symbolized by the "***2° goal***".

Which service do societies expect from science to deal with the challenge of complex dynamics? In public but also among some scientists, the expectation is often voiced that scientific insights dictate certain political decisions. I personally believe that such an approach is not only over-charging science but is inconsistent with the idea of democratic decision-making.

Scientific knowledge enables often significant evaluations of options for decisions. This suggests a ***division of labor between policymaking and science***: science is analyzing options of decisions; the authority of science is rooted in the scientific methodology and not in societal satisfaction with results. Policymaking, on the other hand, is selecting from the options according to not only the scientific evaluation of feasibility and consequences but also societal preferences and conceptions. This constitutes a coupled division of labor which pays respect to the specifics of the societal actors "science" and "policymaking", and recognizes the democratic legitimization of public decision-making.

So far my overall summary; in the following I will try to add more depth to the different points.

Let me start with the ***scientific knowledge about climate***. ***"Science" refers here to what in Germany is called "Naturwissenschaften"***. When speaking about "climate science" I refer to the physically based part of this field, which deals with past developments, mechanism, linkages, detection and attribution, scenarios and direct impacts.

All sciences, also climate science, develop; they solve some issues and find many new ones. ***Science is not presenting eternal truth, but best explanations irrespective of societal preferences. These best explanations are tested again and again and are in many cases eventually replaced by an even better explanation.*** These explanations are considered legitimate, because they have been generated with the scientific method, and because scientists have permanently tried to falsify them by challenging them with other data or other scientific knowledge claims.

The scientific community is transferring these best explanations to society at any given time, but knows very well that they may need to be revised in some future, when new observations, data and knowledge become available. Science appears as a social process, which is conditioned by social conditions and values - which has been worked out by the Polish theoretician of science ***Ludwik Fleck*** in his seminal book “Genesis and Development of a Scientific Fact“.

The public recognizes “the” science as an authority in explaining linkages and dynamics. “The” science is often perceived as representing objectivity, i.e., independence of personal, economic, or political goals. However, the actors of science are part of society and its socially constructed knowledge claims. But society seems to consider this obvious inconsistency not to conflict with the societal attribution of science of providing truth.

The scientifically constructed knowledge of climate change and its impact is subject to uncertainties, to doubt, and to tentativeness. This does not mean that this knowledge would be arbitrary or even corrupted by cheating or would be practically irrelevant. Indeed some knowledge claims are very solid after having seen many attempts for falsification, while others are brand-new and untested.

Scientifically constructed knowledge develops like a tree – each year new rings form and with it new knowledge claims. The newest rings are particularly touchy, since they are subject to critique and falsification. That said, the often claimed “***newest scientific results***” should be looked at critically and not considered as being particularly valuable and “good”. In the course of time, when these “newest results” have survived the fire of falsification, these newest knowledge will transform to solid, broadly accepted knowledge. Therefore it is important, that scientific communities try to establish, which part of contemporary knowledge is complete and generally accepted, and which parts are preliminary, incomplete and contested. The ***IPCC reports*** are a

good example of such efforts of assessing the quality of contemporary knowledge claims about climate change.

Solid Knowledge: Detection and Attribution

Which part of the scientific knowledge about climate change is solid, is uncontested? Which assertions are accepted in the scientific community, no longer subject to critique and opposition? Here, I refer to critique and opposition of scientists, who are actively involved in scientific research about recent and possible future climate change.

Uncontested is that climate is changing; almost everywhere, and of course in the global mean, it is getting warmer. In Germany, the warming since 1880 is about 1.3° according to the German Weather Service and German Meteorological Society. This warming is not an artifact related to the selection of measuring sites or to changing measuring methods or practices. Indeed, in our series of now five consecutive surveys[1] among international scientists since 1996, we find ***95% and more among the respondents to agree to the reality of ongoing climate change***.

The next question is: ***is this recent warming within the range of variations generated by the climate system itself?*** Also in this case there is a broad consensus. Given our present knowledge about natural climate variations, the recent warming is found to be larger than what has to be expected from natural variations. Thus, external factors must be active. The technical term is "***detection***". Thus we have detected a climate change, which needs an external factor for explanation. Candidates of possible factors could be the steadily increasing presence of greenhouse gases, in particular carbon dioxide, but also aerosols related to industrial activity or volcanic eruptions, changing land use such as deforestation or urban warming, or changing output of the sun.

For the detection task, climate models play a minor role – detection is a statistical analysis of the observational record, which needs to be of good quality.

The second step deals with question, which external factors may be dominant for the recent climate change. The name of this step is called "***attribution***". While detection takes the form of a successful statistical rejection of a null-hypothesis, attribution represents a plausibility argument – it is possible that there are more possible causes than we presently know. What we do for

[1] Bray, D., and H. von Storch, 2016: The Bray and von Storch 5th International Survey of Climate Scientists 2015/2016. *HZG Report* 2016-2

attribution is comparing the observed recent change with suggestions prepared by climate models for the response to the candidate forcings, such as elevated greenhouse gas levels. When the observed change, which was detected as having an external causes, is consistent with the response to a mix of causes, and inconsistent with all other causes, then we choose this mix as the most plausible. In our case, this mix is dominated by the response to elevated greenhouse gas concentrations, with minor contributions by solar activity and regionally varying contributions by anthropogenic aerosols, and of course the ubiquitous internal variations.

The approval to this attribution is between 80% and 90% in our last survey, from 2016 - of course below the approval to the claim of climate change. A really large approval, but smaller than the famous 97% claimed by activists including President Obama.

A byproduct of attribution is the indication that the effect of increased greenhouse gas concentrations in the atmosphere is likely realistically described by the climate models. The various models do not suggest the same response to increased greenhouse gas concentrations, but their responses are consistent, and the differences reflect the inherent uncertainty of a high-dimensional nonlinear system with significant internal unforced variations plus model inaccuracies. Therefore, it is plausible that such models are capable to describe to first order approximation possible future states influenced by the considered external factors. In other words: scenarios constructed with such models provide a framework for planning adaptation and for estimating the efficiency of climate protection policies.

The procedure of determining that climate is really changing, that it is changing beyond the range of natural variations, and determining that elevated greenhouse gas concentrations have a dominant role in our explanation for the change is employed successfully for ***global and regional air temperature***. For regional precipitation in Europe, both seasonal sums and extreme values, “detection and attribution” has not yet been successful, which may be related to either too strong natural variations or not yet strong enough change signal. Also, it may be that a second factor, namely the very successful air quality policy of the late 20th century is an essential driver of recent change – this air quality policy reduced the regional atmospheric load of aerosols massively.

Unfortunately, environmental NGO’s and mass media have developed the practice of actually attributing all extreme events as being related or even caused by the emerging anthropogenic climate change: whatever it is, flooding,

tropical or regional storms, tornadoes, droughts - these are interpreted as "***signs on the wall***" of the impending climate catastrophe. In most cases the attributions are not based on sound analytical methodology; instead the warning is mostly a predictable ritual connected with requests for intensified efforts in reducing emissions, while prevention for reducing vulnerability to such extreme events is hardly addressed.

Adaptation and Mitigation

For the political discourse about anthropogenic climate change the key question is if anthropogenic climate change is real and may to some extent steered by regulating human emissions of greenhouse gases. This is a scientific question, and climate science has answered this question positively: climate change is getting stronger, when more greenhouse gases are released into the atmosphere. If less greenhouse gases accumulate in the atmosphere, the challenge to deal with man-made climate change is getting simpler.

According to the "***budget concept***", the extent and intensity of climate change at the end of the century is to first order approximation proportional to the total amount of released greenhouse gases since the beginning of industrialization in the mid-19th century. The budget concept is a very convenient tool, which has been endorsed as valid by the latest report of the IPCC. We can estimate how much greenhouse gas may be released in the coming years and decades, if the societies of the world want to limit warming by for instance by 2°. Also, the issue of which society will emit how much can be framed in this context using justice, history or other arguments.

The budget concept makes also very clear, that we have already a significant man-made climate change because of the past emissions. This change cannot be undone - at least as long no significant efforts for removing greenhouse gases from the atmosphere are established. Already now there is a significant ***need for adaptation*** to already emerged climate change, and this need will continue expanding - also if it is eventually limited by warming of no more than 1.5° or 2°. Adaptation must be a significant issue in particular on regional climate policies agendas, and not only the global challenge of mitigating future climate change - that is the reduction of emissions.

The service of sciences for society

Society expects from sciences support of its decision processes of how to deal with complex issues. In some quarters this expectation takes the form that the societal decision process is subordinated to necessities identified by science. ***"There is no alternative"*** is shorthand. Society has no choice but has to follow the orders of superior scientifically constructed knowledge. I think science is massively overcharged with such a role; also its capital, which is the trust of the public into the purported objectivity of science, is spent - actually spent in a non-sustainable manner.

The view that there would be ***"right" decisions*** on how to deal with the challenge of climate change negates the character of the societal decisions according to societal values and preferences. On the other hand there are certainly *"false" decisions* - they are "false" when the chosen options will not result in the expected effects on the problem at hand. Decisions, which are not "false", can be graded as "better" or "worse" in terms of societally determined values and preferences, but not in absolute terms. I my view ***"There is no alternative" is a deeply and fundamentally un-democratic and apolitical assertion.***

A ***role of science*** is to identify "false" strategies in the range of possible options; and to determine which effects are associated with which treatment. Satisfy these strategies societal preferences? Are the associated costs societally acceptable? These are political questions, which cannot be answered by climate science. Society itself has to find its answers to these questions - and there is no rule in our Constitution that societal choices and decisions need to be "rational" and "sensible" – in fact also "stupid" choices are legitimate.

The role of science is thus the clarification of effects of proposed political measures including in-action. However, climate science can only assess the effects concerning climate and – to some extent – climate impact. Climate science is capable of informing about possible future heavy rainfall intensities, but not on the effect of a carbon tax on low income families or innovations.

Scientific statements about possible future climate change are inherently uncertain to some extent. But this is nothing abnormal for scientific knowledge, which is employed in the political decision process. Political decision processes and public discourses are used to make use of uncertain assertions. ***Uncertainty is no reason for not-acting***.

As an example, I am presenting now our recommendations for future ***coastal defense in Northern Germany:***

The scientific community holds the consensus that sea level will increase in the coming decades of years; in the long term possibly strongly. In the coming 25 years, an increase beyond 30 cm is improbable, so that the present security design for coastal defense should be sufficient. But later, sea level will continue to rise, and this rise may be significantly accelerated. In that case, a fortification and revision of coastal defense may become mandatory in the later years. Therefore it is sensible to use the coming 25 years for

- *Implementing all modernization in a way so that a later time additional fortifications are possible.*
- *Having a solid monitoring program for determining the real rise of regional sea level.*
- *Investing into new technologies, such as improved dike surfaces, which withstand higher spillover during storm surges.*
- *Participatory processes with local stakeholders dealing with the acceptability of possible future coastal defense strategies.*

This example demonstrates how scientific knowledge may be used for exploring options, without scientists acting as activists who try to convince society to adopt a certain option. Scientific knowledge plays an important role, but decisions are made by societal actors. ***This is an example of sustainable uses of the societal resource "science".***