Once upon a Time I was a Nuclear Physicist. What the Politics of Sustainability can Learn from the Nuclear Laboratory

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This paper keeps pace with my personal history as a researcher: starting from the eagerness for knowledge of the nuclear physics PhD student I once was, continuing with my search for social relevance in policy-preparatory research I subsequently performed as a sustainability scholar, it finally leads to the topics of interest for the hybrid philosophy-sociology researcher I am today. Following these traces, I first of all rethink my life as a physicist in terms of science as a necessarily situated and engaged practice before laying bare the baleful scientisation of politics in sustainability discourse. Finally, I sketch the contours of a genuine politics of sustainability by repositioning the enigma of scientific production at the heart of its practice.

Preamble

"Once upon a time I was a nuclear physicist"; it reads like the beginning of a fairy-tale and at the moment I started my PhD in experimental nuclear physics at Ghent University (Belgium) in 1997 it also felt like a dream that came true. Since I was a high school student I had been fascinated by physics and more particularly by the idea that physics would lead me to a fundamental understanding of "Life." Indeed, I wanted to understand what the world is made of and why the world is as it is. Or to put it in Heidegger's words, taken over from Leibniz, I wanted to understand "why there is something rather than nothing" (Heidegger 1949). At that time, physics seemed to me the most obvious and profound way to pursue

It is a pleasure to dedicate this paper to Don Ihde. I owe a great deal to his early encouragement in pursuing my own way. I am also grateful to Filip Kolen who is an invaluable source of topical criticism to my work and in particular to this article. I thank Robert Scharff for his insightful comments on an earlier version of this paper and the anonymous referees for their remarks and suggestions. This work was supported by a postdoctoral fellowship of the Research Foundation—Flanders (FWO).

Perspectives on Science 2011, vol. 19, no. 1

such a quest. Starting a PhD in nuclear physics, in those days still considered the queen of sciences, with the prospect of doing experiments in the world's leading experimental facility, CERN, felt like entering God's factory: at last I would get to understand what the world is made of. It turned out slightly different. As I see it now, and as I will explain in more detail further on, I ended up, not in God's factory, but in a human factory of facts. Very unsettling for me was that my fundamental questions did not seem to matter in this factory. Together with more reflexive questions on the scientific practice, my questions about the nature of the facts we produced were deemed irrelevant: the facts were the facts. So, after five years of producing and publishing scientific facts (e.g., Goeminne et al 2000 and Goeminne et al 2002), I set out looking for a research position with "social relevance." That is how I left the evident path of an academic career in nuclear physics and got engaged in policy-oriented research at the Centre for Sustainable Development of Ghent University, where societal issues are addressed in a multidisciplinary approach integrating both environmental and social perspectives (e.g., Gerlo et al 2003; Paredis et al 2009). I worked for five years on the interface between science and policy: based on scientific facts, produced in some human factory of facts, I now produced policy relevant knowledge, often summarized in the form of concrete policy recommendations. Throughout these five years of so-called "boundary work" (Jasanoff 1990), I was confronted with a problematic aspect of the science-policy interface in sustainability issues: scientific facts were regarded as untouchable and absolute in environmental disputes, leaving no room for any non-scientific arguments. Here again, the facts were the facts. At that point, things started to fall into place. I saw that the reflexive questions I had posed about the epistemological and ontological status of scientific knowledge when I was producing facts in the nuclear laboratory are of crucial importance and relevance when looking at the role of scientific knowledge in the political organization of society. I got convinced that, as Latour phrases it, "the enigma of scientific production must be repositioned at the very core of political ecology" (Latour 2004a, p. 4).

In this paper I want to follow up on Latour's call through a meticulous unraveling of the research questions that have guided my personal "repositioning trajectory." In this respect, I will not so much treat my nuclear physics history as a (laboratory) case study.[1] Rather, I will draw on my personal history in order to show how an enduring interest in the questions of science, rather than in the answers it provides, brings the inherent political dimension of "science in the making" to the fore. So, in the first part I

1. Although this would certainly be interesting in its own respect. See further.

present three types of fundamental questions I had about the experimental practice in the nuclear laboratory and elaborate how these questions give rise to my account of knowledge production as a necessarily situated and engaged activity. In the second part I will try to show how this "engaged knowledge" view gives rise to reframing the science-policy interface beyond the fact-value dichotomy. What seem worlds apart should be regarded as two of a kind. Although it repudiates its inherent normative character, science is through and through political in the way knowledge production enables and constrains human choice. Analogously, politics ignores its objectifying nature although its attempts to order society instruct a worldview that enables and constrains possible orderings of nature. To conclude this introduction I want to mention that in a very particular but important sense, I do not see another way to present my current research topics than in such a historically structured approach. In line with the account of engaged knowledge I will elaborate in this paper, they are the non-neutral results of my historical engagement: interests, such as research topics, do not float free in a vacuum; they are always connected to a contingent history that, ex-post, gets the status of a necessary history. In my view, this autobiographical trajectory adds weight to the paper's central argument: how could I argue for a questioning of science's questions without questioning my own?

1. Engaged Knowledge in the Nuclear Laboratory: Upon Entering God's Factory and Finding a Human Factory of Facts

As mentioned above, in the autumn of 1997 I entered what I thought was the gate to God's factory, the world of nuclear physics. Here, finally, I would discover the fundamental laws and entities that make up the world. Noteworthy (and I will come back to this later), the world of nuclear physics is a world filled with not only human beings but also technological artefacts such as particle accelerators, nuclear reactors, particle detectors, electronics, and computers. In a first step however, I will briefly explain what I did during my stay in this world in a naïve realistic way, taking for granted the meaning and interpretation that nuclear scientists give to the phenomena encountered there, without questioning the way human beings make sense of the phenomena in the nuclear laboratory, and how this sense-making is possible after all. Or to put it in Kuhnian terms, I will be taking for granted the paradigm of experimental nuclear physics. As such, it will be a realistic account in terms of neutrons, protons, alpha particles and atomic nuclei interacting with each other as if billiard balls were colliding in front of my eyes. This paradigmatic, non-critical account will not only set the stage for further reflections, it also gives a feel for the obvious character, the taken-for-grantedness of the absolute perspective scientists, or at least part of them, believe to hold.

1a. What Happens in the Nuclear Laboratory? An Account from Within the World of Nuclear Physics

The title of my PhD dissertation reads as follows: "Investigation of the (n,p) and (n,α) reactions on ^{36}Cl, ^{37}Ar and ^{39}Ar and their astrophysical relevance" (Goeminne 2001). Starting from this title, I will try to explain what I did during my PhD, beginning with the term "astrophysical relevance." Is there any astrophysical relevance for nuclear physics, one might ask? Indeed, it is now commonly believed that all elements occurring in nature, i.e. those to be found in Mendeljev's Periodic Table, have been produced through nuclear reactions either early on during the Big Bang or later on in stars and the interstellar medium. "We are all stardust" is a much-quoted sentence that phrases the idea that all the chemical elements that make up our bodies, e.g. carbon, iron, etc. . . were created billions of years ago in the hot interiors of remote and long-vanished stars. Nuclear astrophysics, at the interface of nuclear physics and astrophysics, is the branch of nuclear physics that deals with explaining the formation, via nuclear reactions, of all the naturally occurring chemical elements in the universe. In this naïve realistic interpretation, one can say that nuclear astrophysics—quite literally—tries to understand what the world is made of and indeed deals with the fundamental questions that led me to physics in the first place (see Preamble). I will come back to this point later, when speaking of topical truth (see 1.c.3. On topical truth and co-constitution)

Stellar nucleosynthesis theory, i.e. the theory that aims at explaining the natural abundance (prevalence) of the chemical elements and their different isotopes[2] is on a firm basis now. Big Bang and stellar models indeed show how, starting from a certain amount of Hydrogen created during the Big Bang, all elements, going from Helium to Uranium, can be produced through nuclear reactions.[3] However, a few "problematic elements" remain; i.e. elements for which the production mechanisms, i.e. the nuclear reactions, are not fully understood. One of these problematic elements nu-

2. An element or atom, which is defined by the number of protons in its nucleus, can have different stable isotopes, differing in the number of neutrons contained in its nucleus. This is made clear by mentioning the number of neutrons as an upper index. S (sulphur) contains 16 protons and has four different stable isotopes. The isotope containing 36 neutrons in its nucleus is thus symbolized by ^{36}S. This isotope has a natural abundance of 0,02% of the total S abundance.

3. For an encompassing overview of nucleosynthesis theory, the reader is referred to the classic volume of Rolfs and Rodney entitled *Cauldrons in the Cosmos,* the title indeed suggesting the idea of a theory of origins (Rolfs et al 1988).

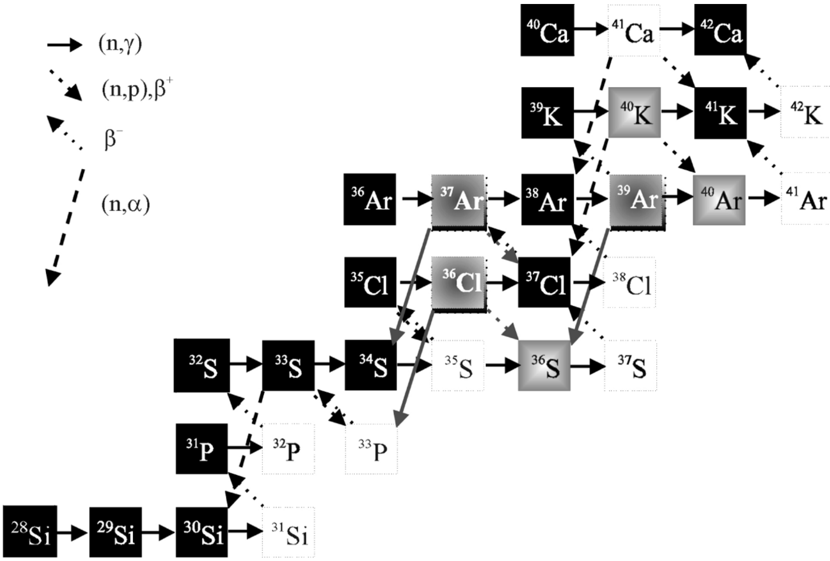

Figure 1. The nucleosynthesis network in the region between Silicium and Calcium. Shown is the myriad of possible nuclear reactions taking place in stellar interiors and transforming one isotope into another. (taken from Goeminne 2001)

clear astrophysics fails to reproduce in its stellar model calculations is the neutron rich sulphur isotope ^{36}S. This isotope took centre stage in my PhD research where I tried to solve the puzzle of the origin of the ^{36}S isotope by investigating some missing elements in explaining its production mechanism.

In Figure 1 one can see a schematic picture of the model we used in reproducing the ^{36}S abundance in nucleosynthesis theory. As an illustration of how to "read" such a "nucleosynthesis network" one can see for instance, following the arrows that lead to ^{36}S in Figure 1, that ^{36}S is directly produced through three different neutron induced reactions,[4] i.e. ^{35}S(n,γ)^{36}S, ^{36}Cl(n,p)^{36}S and ^{39}Ar(n,α)^{36}S. Of course, the final abundance of ^{36}S will—to a certain extent—be dependent on all the possible reactions in this network as all of them, either directly as illustrated above, or indirectly influence the abundance of this isotope. So, if one wants to calculate the

4. Writing down a nuclear reaction where a projectile i interacts with a target nucleus X producing a product nucleus Y and an ejectile e, is commonly done as follows: X(i,e)Y. ^{39}Ar(n,α) ^{36}S should thus be read as the nuclear reaction of a neutron interacting with a ^{39}Ar nucleus producing a ^{36}S nucleus and an alpha particle.

final abundance of ^{36}S that is reproduced through this model one basically needs the following input data:

- The probabilities of all the nuclear reactions involved as a function of the stellar temperature
- Stellar parameters such as stellar temperature and neutron density
- The abundance of the so-called "seed nuclei," i.e. nuclei already present in the star at the moment that the myriad of reactions depicted in the model starts to take place

As mentioned before, the abundance of ^{36}S has not been reproduced adequately through this model, which basically leaves the following options:

- The stellar parameters are wrong
- The abundances of the seed nuclei are wrong
- The probability of the nuclear reactions involved are wrong
- The model is wrong which would put stellar nucleosynthesis theory in question

The first two types of data, i.e. stellar parameters and seed nuclei abundances, are well known from stellar observations.[5] So, within the paradigmatic contours of nucleosynthesis theory, i.e. leaving stellar nucleosynthesis theory unquestioned, one is left with the hypothesis that the reaction probabilities are not correct. As a few of them had never been experimentally determined before and for which up to then theoretical estimates had been used, we decided to experimentally measure the probabilities of a few reactions of the nucleosynthesis network which play an important role in the production of ^{36}S: $^{36}Cl(n,\alpha)^{33}P$, $^{36}Cl(n,p)^{36}S$, $^{37}Ar(n,\alpha)^{34}S$, $^{37}Ar(n,p)^{37}Cl$ and $^{39}Ar(n,\alpha)^{36}S$. In brief, we tried to reproduce these nuclear reactions in the laboratory in order to study its properties. In particular, we wanted to obtain the reaction probability as a function of the energy or, translated back into astrophysical terms, how likely it is that a certain nuclear reaction will take place at a certain stellar temperature.

How this was done in the laboratory is schematically depicted in Figure 2 showing the experimental setup. A beam of neutrons, produced in a linear accelerator (LINAC), is aimed at a target (respectively ^{36}Cl, ^{37}Ar or ^{39}Ar) that is contained in a detector. The latter is a so-called Frisch-grid Ionization Chamber (FIC), the inside of which is shown in Figure 3.

5. In a terminology that will be further elaborated, one could say that these are "stable" scientific facts. Fundamental questions may be posed concerning "stellar observations" in the same line of the questions I will pose regarding "nuclear physics observations." However, I will not elaborate further on this point here, as it is not relevant for my story, thus taking for granted the "correctness" of these types of data.

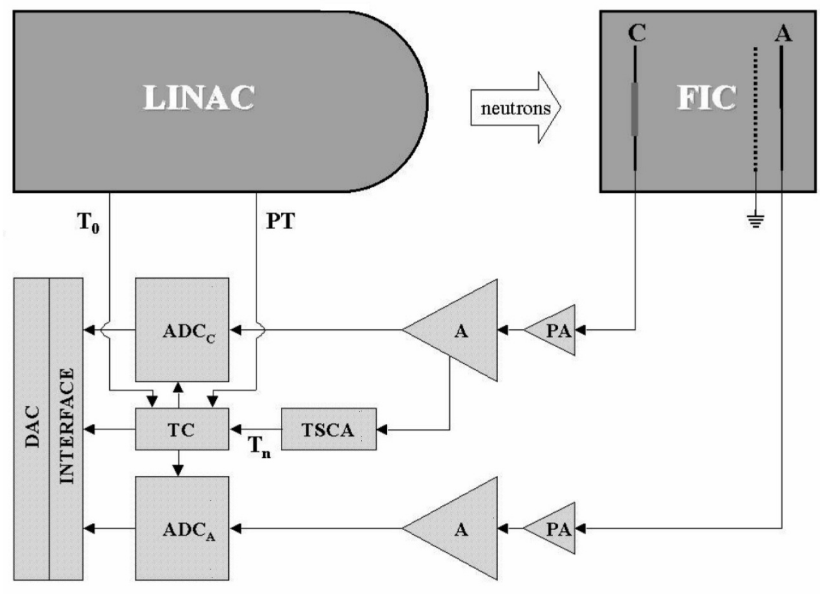

Figure 2. A schematic picture of the general experimental setup used throughout my PhD research. (taken from Goeminne 2001)

When a neutron hits e.g. the ^{37}Ar target, and the $^{37}Ar(n,\alpha)^{34}S$ reaction takes place, an $\alpha-$particle is emitted out of the target foil (contained in the cathode (C)) into the ionization chamber where it deposes its energy and comes to rest. Through this ionization process, the proton energy is transformed into electric signals on both the anode (A) and cathode (C), which are further given shape by a lot of electronics (pre-amplifiers (PA), amplifiers (A), time-coder (TC), analog-to-digital-convertor (ADC)) before being fed into a computer-based Data Acquisition System (DAC). This results in so-called energy spectra for both the interacting neutrons and the ejected alpha particles.

In Figure 4 one can see such an energy spectrum for the emitted alpha particles from the $^{37}Ar(n,\alpha)^{34}S$ reaction studied in Goeminne et al (2000). From such a spectrum the amount of reactions that took place can be deduced by selecting the "relevant events," events being represented by the dots in the spectrum. In this case the rectangular bump in the upper right corner represents the relevant $^{37}Ar(n,\alpha)^{34}S$ reactions whereas the bumps in the lower and upper left corner are due to irrelevant alpha particles and protons resulting from neutrons interacting with so-called "con-

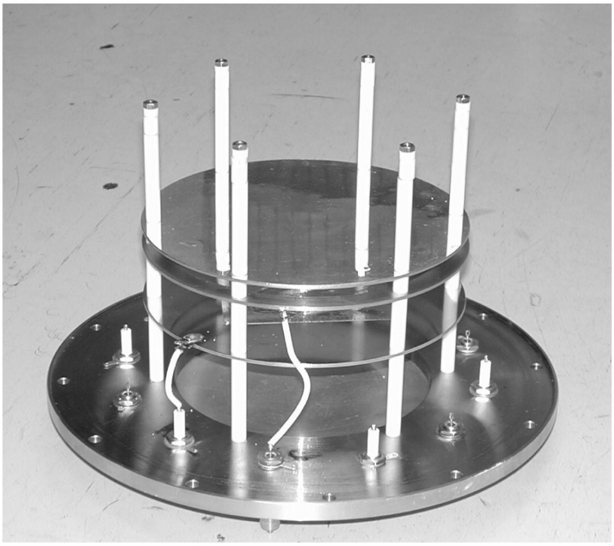

Figure 3. Picture of the inside of a Frisch-grid Ionization Chamber (FIC). From bottom to top, one can identify respectively the aluminum entrance window, the cathode containing the target, the Frisch Grid and the anode. (taken from Goeminne 2001)

taminations" present in the detector. The singular points spread out all over the spectrum are attributed to non-differentiable, irrelevant background events. Accounting for the non-relevant contamination and background events then finally allows calculating the reaction rate for this reaction. This data gathering process has to be averaged over several days or even weeks in order to get statistically relevant, reliable results. Throughout the experiment, the external conditions (pressure in the ionisation chamber, working parameters of the accelerator, etc.) are constantly monitored and kept stable. The same procedure, with some slight adjustments, was followed for all five reactions under study. The reaction rate data so obtained were then fed back into the stellar nucleosynthesis model. The new data changed the value of the "produced" ^{36}S abundance slightly, but the model reproduced still only 2% of the natural abundance. This leaves the quest for the origin of ^{36}S open. Either new nuclear reaction data are needed or otherwise another production model for ^{36}S has to be looked for. The latter would change our understanding of how ^{36}S is produced in a star and thus also our understanding of what a star is and how it works.

To conclude this report on my experimental life it is noteworthy that at that time, the kind of pseudo-scientific language I have been using here

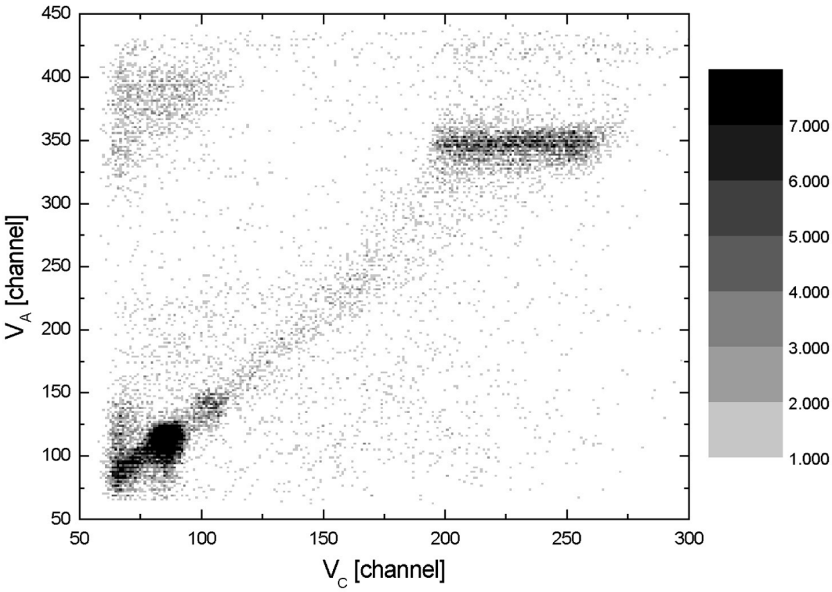

Figure 4. The energy spectrum for the $^{37}Ar(n,\alpha)^{34}S$ reaction studied in Goeminne et al. 2000. The abscissa and ordinate respectively depict the cathode signal pulse height (V_C) and the anode signal pulse height (V_A). (taken from Goeminne 2001)

was almost my natural language within the laboratory. It was indeed completely normal to talk in terms of neutrons hitting protons as if we were talking about billiard balls hitting each other on a billiard table in front of our eyes. This was how we made sense of what we did. Now, some 10 years later, I have a hard time adopting this language once more. Using this language now, I can no longer make sense of what I did then. So, from now on, I am changing to a discourse in which I think I can make sense of it.

1b. Questioning Laboratory Practice: How, What and Why?

Once entered in God's factory, I progressively became aware that the fundamental questions I had been posing to myself and which had led me to the study of physics in the first place would never find an adequate response there. Also, more reflexive questions regarding the practice of nuclear physics were typically deemed as irrelevant or non-scientific. Looking back, I now see that my questions from that time can be ordered under three typologies: How-questions related to the practice of experimental nuclear physics, i.e. "How does nuclear physics work?"; What-questions related to the metaphysics of experimental physics, i.e. "What is it that nuclear physics is about?" and Why-questions related to the relevance of nuclear physics, i.e. "Why should we engage in nuclear physics?" Below, I expand on these three categories of questions, adding some typical autobiographical examples.

• *How-questions*

This category contains questions about the social and technological context, i.e. the experimental community and its machinery and its role in the production of scientific knowledge: "(how) do we interfere in an experiment?," "are we neutral observers?," "what does it mean to be neutral?," or "(how) do the technological instruments play a role in the scientific practice?" Such questions were put aside, taking for granted the non-interestedness, the neutrality, i.e. the objectivity of scientists and technological artefacts: "we do not interfere in the experiment." More specific questions often dealt with the experimental practice such as: "how do you know when an experiment is running well?" or "how do you know that a certain electronic signal is not relevant?" The typical reasoning in tackling this sort of question went as follows. As long as the experiment is not stabilised, the electronics is said to produce "jitter" or even "rubbish" and vice versa. Calling a phenomenon jitter or rubbish is equivalent to saying that it is not worth considering it as a fact. An experiment that is not stable is not reproducible and can thus not deliver facts: the general requirement of objectivity in science seems to boil down to one of reproducibility in experimental (nuclear) physics.

• *What-questions*

This type of question deals with the content of the observations made and more specifically with the reality of the scientific facts, e.g., "what is it that we observe when we look at an energy spectrum?" and "are neutrons real?" Questions like these were easily put aside. Sometimes, in a wave of open-mindedness, it was argued that these kind of questions might be interesting for philosophers but not for physicists. More often a more defensive stance was taken using an argument as "what are we doing here if you doubt that neutrons are real?" And once in a while, you got a rather offensive reply saying: "Would you like to put your head into a neutron beam to see if they are real?"

• *Why-questions*

Here, questions regarding the (social) relevance of nuclear physics are at stake, e.g., "Why are we doing this?," "Why is this interesting?" The classical answer here goes as follows: "You should not bother about such questions; the fact that we do not bother about the social relevance of our work is a precondition to perform fundamental physics work; we can only be interested by the truth, that is, by the objective facts we discover. It is exactly our non-interestedness that guarantees good science and objective knowledge that, though this is not our business, eventually, in one way or another, will deliver for society." In that respect, I have always found it remarkable and even funny that almost every scientific paper contains a paragraph, often entitled "motivation," in which it is explained why the research reported on is interesting (See, e.g., Goeminne 2000). These kinds of motivations lack any reference to the lifeworld and generally evolve along the following pattern: "this nuclear physics research is interesting because it delivers fundamental nuclear physics knowledge" or, more in line with my own PhD project "because it is of importance for a better understanding of nucleosynthesis theory." In my present view this boils down to saying "physics is interesting for physics." There may be nothing wrong with an interest in scientific knowledge just for its own sake, but then I do not understand why physicists, who proclaim that non-interestedness is a necessary condition for good scientific work, do feel the necessity to torture themselves by writing such a motivation. In my present view (see following section 1.c.: The co-constitution of objectivity and subjectivity: knowledge production as a necessarily situated and engaged activity), this claim for non-interestedness as a necessary quality for good scientific work should rather be interpreted as an interest in itself, as a particularly interested and "engaged" way of looking at the world.

The latter point is also what ties my own how-, what- and why-questions together. At a certain point during my PhD, neutrons no longer existed for me (what-question) in the sense that the way the neutrons were supposed to reveal their existence (how-question) no longer made sense to me. As I see it now, this was precisely because I no longer had an answer to the why-question; I no longer saw the sense in studying the world from this "non-interestedness" perspective. And vice versa: as electrons no longer revealed their existence to me through the experimental procedure, I could no longer see the interest in studying nature the way we did. In searching for a way out of this impasse and for an answer to my how-, what- and why-questions, I progressively became aware of other fields of research where these kinds of questions are not deemed as irrelevant or non scientific, in particular in philosophy of science and technology, and in science and technology studies. Engaging with Don Ihde's *Instrumental Realism* (1991), which situates itself on the interface between philosophy of science and philosophy of technology, was a revelation to me: I realized that my questions *did* matter and were interesting.[6] This encounter set me off on my journey away from the world of doing science into the world of thinking about science. This journey has now come to a point where my original questions have grown into an account of science as the necessarily situated and engaged activity I will elaborate on below.

1c. The Co-Constitution of Objectivity and Subjectivity: Knowledge Production as a Necessarily Situated and Engaged Activity

1.c.1. On Technological Mediation and Co-Constitution In classical philosophy of science, science does open the gate to God's factory: scientific theories are indeed considered as straightforward representations of nature, with experiments providing "empirical data" to verify or falsify those theories. However, as I mentioned before, the world of experimental nuclear physics is above all a world filled with human beings and modern, specialised technological artefacts such as particle accelerators and detectors: it is a human factory of facts. With the work of Kuhn, a substantial criticism on the neutrality of scientific practice was formulated (Kuhn 1962). In Kuhn's analysis, social factors can play an important role in the decision process between alternative paradigms. Post-Kuhnian thinking, in particular social constructivism, has concentrated on the social context of scientific knowledge. Such a one-sided social-contextual approach of scientific practice however, does not allow for a symmetrical, critical analysis of the social constitutive elements of science (Latour 2005). In the constructivist approach, social aspects such as values, interests and concerns are treated as *a priori*'s, black-boxed and as such excluded from further analysis. In the same line, social constructivism has mostly neglected the essential role that scientific artefacts (particle detectors, accelerators, etc.) play in delivering the facts; it has always reduced this technological dimension, in its alleged neutrality, to human agency and thus to the social context. Philosophy of technology of recent decades however offers some important insights that fundamentally question the neutrality of technology in its relation to individual human beings and society as a whole.

6. This work of Ihde not only opened the gate to his whole oeuvre, but also to a broader development in philosophy of science that Ihde himself has called "instrumental realism" (Ihde 1991). Ian Hacking, Bruno Latour, Andrew Pickering and Peter Galison are amongst the scholars Ihde mentions in this context: all of them have taken seriously the role of scientific instrumentation in the constitution of knowledge. In the following it may be clear that my own account of knowledge production in the nuclear laboratory inscribes itself in this development. In this respect, a detailed laboratory study of my own nuclear physics experience could be of great interest, providing for instance an opportunity to contrast Ihde's postphenomenology and Latour's Actor-Network-Theory. As already mentioned, however, this lies beyond the scope this paper.

Since the "empirical turn," the totalitarian approach viewing technology as an autonomous system has been challenged by a more differentiated view focussing on the role specific technological artefacts play in human actions and experiences (Achterhuis 2001). In Ihde's philosophy of "technological mediation," technological artefacts co-constitute reality (Ihde 1990, pp. 72–123). On the one hand, they mediate how human beings are present in their world, by shaping their actions and existence; and on the other, they mediate how the world is present to human beings, by shaping human experiences and interpretations of reality (Verbeek 2005). In my view, this is perfectly applicable to the nuclear laboratory. The whole experimental setup, ranging from the particle accelerator over the ionization chamber detector to the data acquisition system, can indeed be interpreted as one big imaging technology producing spectra that need to be interpreted before anything relevant can be said about the world. Adopting Verbeek's terminology, one can discern the "hermeneutic dimension" of technological mediation here: the experimental setup mediates the way the world is experienced and interpreted in the laboratory (Verbeek 2005). Or, switching again to Ihde's words: the experimental set-up acts as a "hermeneutic device" (Ihde, 1999). But more can be said when we shift our focus away from a "stable" and "interpretable" experiment to the practice of setting up an experiment. Here, technological artefacts are always involved in a typical cyclic process of designing-testing-adjusting-testing. Pickering refers to this process in terms of "resistance and accommodation" (Pickering 1995): you set up an experiment based on an existing theory, or, in the case of a revolutionary phase of science, a preliminary, hypothetical theory. But an experiment never works from the first time: nature resists, so to speak. So, in a next step, you adjust your experimental setup, i.e., your technological apparatus and, in the case of a revolutionary phase of science, you may also want to change your theory: You try to accommodate the resistance of nature by adapting your experimental setup both in its instrumental embodiment as in its theoretical, hermeneutic interpretation. And then you test again and so on and so on. Eventually, this results in a stable, reproducible state in which valid observations can be performed. At this point of stability, of reproducibility, everything falls into place: the technological artefact takes its final, "stable" shape: it "works" and the scientific knowledge takes its final, stable shape: it is "valid"; it is "objective." From this description of how reproducibility comes into being it should become clear that I interpret this particular objectivity, i.e. reproducibility, as the crystallisation, the sedimentation, of a situated stabilization process. In this respect, the objective reality of physics, e.g. neutrons, is constituted in a situated scientific activity: neutrons are the crystals which grew out of a complex stabilization process in which situated humans, machines, and objects continuously constitute each other. In the next paragraph, building on the Kuhnian paradigm concept, I want to elaborate on how the constitution process of an objectivity, is intrinsically coupled to the constitution of a subjectivity.

1.c.2. On Kuhnian Paradigms and Co-Constitution In Kuhn's interpretation, a paradigm is mainly responsible for the theory-laden character of observation (Kuhn 1962). The content of observation is co-determined by the theoretical presuppositions; theory gives "mere" facts an interpretation and meaning. I would like to take this one step further and regard a paradigm as a necessary condition of possibility for observing facts. In my view, a paradigm is what makes it possible to "see" facts; it co-constitutes the facts and as such it shapes the content of the resulting scientific knowledge. This interpretation of Kuhn's paradigm is in line with Husserl's notion of perspective (Husserl 1970). According to Husserl's view, the (subjective) perspective is truly constitutive for objectivity: the objective world is not given as such, but is the result of a process of transcendental constitution. Whereas Husserl's constitution process is however still bound to an absolute ego-pole, I am adhering to a more dynamical variety which is in line with a postphenomenological account, developed by Ihde and further elaborated by Verbeek in a technological context (Ihde 1995; Verbeek 2005). Here, objectivity is no longer seen as originating from the autonomous activity of an *a priori* given subjectivity. Rather, both subjectivity, i.e., the paradigm and its accompanying objectivity, are mutually co-constituted in the process that "discriminates" them.[7] Obviously, I am talking about "first," "revolutionary" experiments: once a "first" experiment stabilizes, both the paradigmatic rules and their accompanying objectivity are institutionalized. In this sense, objectivity is not something external, something to be found "out there"; it is constituted in the situated genesis of a paradigm and crystallises out at the point of stability. From then on, a new member of this particular paradigmatic science should first adopt this paradigm before he can "see" its accompanying objects. One has to become engaged—just as I had to adopt the experimental neutron physics paradigm before I could "see" alpha particles and protons in the bumps in an energy spectrum (Figure 4). When I was first confronted with such a spectrum, there was no way I could make any sense of it. Someone, i.e., an experienced scientist, had to make clear what

7. In this respect, there is a certain sense in which Ihde, although restraining from anything like a Husserlian transcendental ego, can be thought of as having developed a more radical version of Husserl's constitution account. For Ihde, not only the objective world but also the pole of subjectivity has to be "bracketed" or "suspended."

counts as relevant or not: "look, these (pointing at the bump in the upper right corner) are the alpha's we are looking for and maybe here (pointing at the smaller bumps in the lower left corner) are some protons, but it may also be alpha's from a $^{10}B(n,\alpha)$ contamination which is always present in our detection system although we don't know where it comes from." This "becoming aware" of what counts as relevant or not within the nuclear physics perspective is what I would call "becoming engaged." It took months and even years to grasp the whole chain of technological mediations and hermeneutic interpretations that precedes the interpretation of an energy spectrum in terms of relevance. But once you get engaged and have adopted the paradigm, it becomes natural and it even becomes difficult to imagine another possible way of interpreting these spectra: there is no other way than to view a particular bump as "consisting" of, e.g., alpha particles. So, I needed to adopt the paradigm of experimental nuclear physics in order to make sense of what happened in the laboratory. It is important to mention here that these energy spectra are already processed data and have thus already been touched by the paradigm of experimental nuclear physics. I could have gone one step further back and show images of the electric signals on the oscilloscope. What I can however not do is go back to "pure" observed phenomena, as I argue that such things do not exist: you cannot make sense of the world without some kind of a paradigm.

Taking back the original "how, what and why" typology of questions I developed earlier regarding my life as a nuclear physicist, it may be clear that up till now I have elaborated on an account of science as a situated practice which takes the intertwinement of the how and what questions as a central feature. There is no priority between practice and knowledge. I see technologically embodied science, such as experimental nuclear physics, as a stabilization process of which both the scientific objects and the technological artefacts are crystallisation products. In elaborating on this account of experimental physics as a situated activity, it has increasingly become clear that it is also necessarily wound up with questions of relevance and engagement, with questions of the why-type that deal with the normative dimensions of scientific activity. In the following paragraph I want to elaborate on this normative dimension, guided by the concept of topical truth.

1.c.3. On Topical Truth and Co-Constitution In elaborating on the astrophysical relevance of my PhD research, I referred to the challenge for the discipline of nuclear astrophysics to gain a complete understanding of how the chemical elements were formed through nuclear reactions in stellar interiors. If you reflect on the way I described above how nuclear astrophysics tries to do this, you see that what is actually being done is an attempt to reproduce the abundances of these elements, i.e. numbers, through model calculations. The issue of the origin of the elements is “framed” in nuclear astrophysics terms: if one claims to understand the origin of a particular element in nuclear astrophysics, it means that he can “reproduce” the natural abundance of this element in a model. I do not claim that this explanation is not valid or incorrect. Rather, I want to focus on what is being explained; that is on the “topic” that is being addressed. In the ensuing discussion on paradigmatic “topics” I will build on the concept of topical truth the German phenomenologist Rudolf Boehm has elaborated and which he has often illustrated by performing a “live” experiment dropping a book and a sheet of paper simultaneously (Boehm 2002; see also François et al 2004). When Aristotle, some 2400 years ago, looked at falling objects, he tried to explain why heavy bodies fall faster than light ones. The Aristotelian theory of gravity states that all bodies move towards their natural place, which causes heavier bodies that contain more of the element of earth, to fall faster towards the earth than lighter ones. Whereas Aristotle tried to explain why bodies fall the way they do on earth in terms of the nature of their substance, Galileo, the founding father of modern experimental science, tried to describe the way bodies fall in terms of mathematical equations. Based on experiments, some 400 years ago Galileo formulated a mathematical universal law for falling bodies: $s = ½gt^2$, which says that the distance covered (s) by a free-falling object is proportional to the elapsed time (t) squared, the proportionality given by one half of the gravitational constant (g). On the basis of this law, Galileo claimed that all bodies, whatever their weight or their substance, fall equally fast. The point I want to make here is that Aristotle and Galileo, adhering to different paradigms, were differently engaged in the world, revealing the world in different ways to them. Whereas Aristotle saw bodies moving towards their natural place according to the nature of their substance, Galileo saw objects obeying a universal law. Aristotle’s topic was the movement of naturally falling objects in our daily lifeworld whereas Galileo was looking for falling objects in artificial experimental conditions in order to reveal a mathematical law. Now, according to Aristotle, heavier bodies fall faster than light ones, whereas Galileo claims that all bodies, whatever their weight, fall equally fast. The obvious question here seems to be: who is right, Aristotle or Galileo? Well, one can do a small experiment and simultaneously drop a sheet of paper and a book. Apparently, Aristotle is right. Galileo would however object and say: “My law concerns free-falling bodies: it is a precise mathematical description of the trajectory falling bodies follow in the absence of our particular earthly circumstances.” “Wonderful such a law!” Aristotle would probably reply, “but what can I do with it as no single object in our lifeworld will ever make such a free fall." So, once again, who was right: Aristotle or Galileo? Apparently, both were right depending on what question science is supposed to answer: the question about falling bodies on earth or about falling bodies in an artificial, experimental environment. The crucial question that imposes itself here is not a question of logical truth, i.e., "Who is right?" but a question of so-called "topical truth." The topical question does not question the truth of the answer to a question; it rather questions the truth of the question that is posed. It is the question of which objects are interesting to be known, i.e., "What issue is at stake?" or "What way of questioning is more adequate?" The point I want to make here is that the choice between the paradigms of Aristotle and Galileo cannot be decided in terms of logical truth, but only in terms of relevance and adequacy, that is of topical truth. So, rather than questioning the validity of a scientific answer or theory I want to question the scientific question itself: "Is it interesting to reproduce the abundances of the natural elements in model calculations and if so, why?" or, in terms of topical truth, "What is the topical truth of nucleosynthesis theory?"

1.c.4. Summarising: The Carpenter and His Hammer or the Physicist and His Neutrons In summary, the three topics addressed above (technological mediation, Kuhnian paradigms and topical truth) sketch the contours of my account of knowledge as a situated and engaged activity. The crucial point to see is that the normative dimension, i.e., the engagedness of science, is already embedded in the situatedness of a particular (scientific) paradigm. Our paradigmatic perspective or "point of view" is the possibility of our "viewing" and at the same time its constraint: it is what enables us to see something standing out; at the same time it necessarily constrains our sight. If we were not directed by a point of view, if we were not bound by a paradigm, we would be embedded in one big undifferentiated flux where nothing could stand out. All this adds up to a relational account of our human "being," i.e., the world is always already revealed to us through our relations with the world, the human-world relation (or paradigm) preceding the related entities. This relational ontology also instructs an interrelational conception of fact and value as always already revealed through a paradigm, through a particular human-world relation. It is for instance useless to talk about the intrinsic value of a hammer, as the latter depends on the human-hammer relation a particular hammer is involved in. Using a hammer when constructing a house, the world is revealed to me through what could be called a "carpenter paradigm." Being involved in the practice of constructing a house, the hammer is revealed to me as a construction device to fix planks to a wall. However, in a moment of anger, engrossed in rage, the hammer may be revealed to me as a killing device. The value of a hammer as a useful construction tool thus depends on the human-hammer relation or the "carpenter paradigm," which precedes both the constitution of the human as carpenter and the hammer as construction device. Just as the instrumental value of a hammer as a construction device is already contained in the "carpenter paradigm" in the sense that the latter reveals to a carpenter-in-practice what is relevant (planks, nails, etc.) and what not (concrete, screws, etc.), so is the "relevance" of the bumps in the energy spectrum as alpha-particles or protons already contained in the experimental nuclear physics paradigm that allows us to identify "relevant" objects at the cost of ignoring, e.g., all of the "background" events which fall out of view of its technologically embodied perspective. The normativity embedded in a particular paradigm is here thematised by the concept of topical truth. Thematising the topics of science, rather than its answers, now opens up a space of thought that may prove enriching in differing contexts. A thorough discussion of the "topical truth" of the questions of science could for instance constitute a genuine task for a "science critics" Don Ihde has been pleading for (Ihde 1997). In framing this kind of "topical questioning" the way I do here regarding my own research topics, I try to make clear how such a "science critics" should go beyond a one-sided negative debunking and deconstruction exercise, which merely results in an undermining of the validity of the scientific answers in question. Rather, it should be understood more positively, along the lines of literary criticism: questioning the strength, beauty, interest, adequacy, etc. of the scientific questions. Furthermore, turning to the crux of this paper, I will argue in the following part that the concept of topical truth is capable of opening up a scientific-political acting space in which fact and value no longer have to be seen as mutually exclusive in addressing sustainability issues.

2. Engaged Participation in a Science-Policy Agora: Repositioning the Enigma of Scientific Production at the Core of a Genuine Politics of Sustainability

I want to pick up on my personal history here at the point where I decided to quit the world of nuclear physics. During the course of my PhD, I got increasingly frustrated with my life as a producer of scientific facts. The story always ended when the experiment got stable and could be reproduced. At that point the facts were observed, the data were processed and, with the aid of stellar model calculations, interpreted in terms of abundances of the natural elements. Eventually all this was concisely reported in the scientific literature. What had fascinated me ten years ago, i.e., knowledge for the pleasure of knowledge, started to frustrate me. Or to state it in line with my account of engaged knowledge: I was no longer convinced of the topical truth of nuclear physics and in particular its engagement of non-interestedness in the lifeworld could no longer hold my interest. Concerned about environmental and social issues, I was particularly bothered by the apparent lack of any social relevance in my work. I no longer felt at home in a world where non-interestedness in the lifeworld and its problems seemed to be a precondition to function well. That is how I set out looking for a job with social relevance: the lifeworld should come at the centre of my attention. And so it went that I left the evident path of an academic career in nuclear physics and engaged myself in policy-oriented research at the Centre for Sustainable Development of Ghent University where societal "sustainability" issues are addressed in a multidisciplinary environment.[8] Here, research is project-based and characterized by a focus on "policy relevance." This not only drastically changed the subject and focus of my research, but also the very way of doing research itself. Whereas in the nuclear laboratory I was guided by the paradigmatic contours of what counts as valid knowledge, I now found myself in a world where facts and values are highly intermeshed and where it is no longer clear what counts as valid knowledge to capture the issue at stake. I conducted the research line on resource consumption and material flows resulting in numerous reports and presentations for local, regional and national institutions and authorities. This required a continuous negotiation not only of what has to be researched but also of what kind of shape this knowledge should have for policy-makers. Throughout these personal experiences with the intermeshedness of fact and value in my research practice, I increasingly struggled with the reigning ideal of "rational decision-making" present in this kind of policy-preparatory work. Not only did I become fully aware of the mere impossibility of separating facts from values, I further came to experience this ideal as a non-workable, counterproductive straitjacket. In this kind of work, I was typically supposed to come up with policy recommendations, which, following the rational-decision making ideal, had to be—or at least presented as if being—the inevitable outcome of objective, value-free research. Although convinced of their relevance and quality, I found it very hard to defend such policy recommendations for the reason that I had to behave as if these recommendations were disconnected from the person who produced them. I felt the need to stand up for these conclusions but was not allowed to do so.

Throughout these five years (2002–2007) of "boundary work" at the science-policy interface, I came to think of this reigning ideal of rational

8. For an overview of the research activities the Centre for Sustainable Development is involved in, see their website: http://www.cdo.ugent.be

decision-making as one of the main reasons, if not the crux, of the impasse of the normative project of sustainable development. In the following, I will first of all elaborate on the roots of this problematic scientisation of sustainability politics. Secondly, I link this analysis up with my concept of topical truth in an attempt to get beyond simplistic demarcations between science and politics. This will allow me to elaborate on what can only be the first delineations of a politics of sustainability repositioned around the enigma of scientific production.

2a. The Sustainability Impasse Called Rational Decision-Making

For more than 20 years, sustainable development has been advocated as a way of tackling deeply intertwined global environmental problems and human development issues such as climate change and poverty. While the broad goals have been widely embraced and sustainable development is now a much quoted policy objective, its implementation seems further away than ever: the cooperative global environmental governance regime envisioned at the 1992 Earth Summit in Rio is still in its infancy while neo-liberal economic globalization has become fully operational with environmental degradation and global poverty still burgeoning. As already mentioned, it is my view that the crux of this impasse lies in sustainability politics finding itself stuck with its self-proclaimed ideal of rational decision-making. Here, science is regarded as mirroring reality and handing over the "natural" criteria for sustainability. Environmental problems, often generated by the products of science, are indifferently framed in techno-scientific terms (CO_2 concentrations, temperature rise, etc.) which inevitably gives rise to a quest for techno-scientific solutions (carbon tax, CO_2 efficient cars, etc.). Consequently, technology is seen as a neutral instrument, a "fix," which can be employed to solve—scientifically framed—sustainability problems. This approach typically argues for an eco-efficiency strategy in which a technology push boosts efficiency levels of natural resource use by a factor 10 and more (Von Weiszäcker et al 1997). Such an expert-focused technological determinism, embedded in a discourse of ecological modernisation, now acts to marginalise the issues of human choice involved in putting sustainability into effect and to downplay deliberation over the socio-cultural practices, behaviours, and structures such choice involves. As a result of this techno-scientific focus, the need for accordant social change is removed from view, which makes sustainability all the less likely to occur in practice. This is convincingly illustrated by the current impasse on climate change that has been created and maintained by making political action subordinate to a scientific framing of what is in essence a societal problem. The narrow scientific focus on global climate change addresses itself to an undifferentiated global "we" and relies exclusively on the authority of science to create a sense of urgency for structural change (Demeritt 2001, p. 329). In the absence of some other basis of appeal, "we" are likely to act as uninvolved spectators rather than participants in the shaping of our future, making responsible, sustainable change all the more improbable to occur.

In my view, this problematic is deeply rooted in the metaphysical and ontological basis our Western society is built on and which also underlies the naïve realistic interpretation of science that resided in my nuclear laboratory (see Section 1): a frame of thought, in which subjectivity and objectivity are seen as mutually exclusive. Objectivity, on the one hand, is what science strives for; it is the realm in which truth is to be situated. Either our knowledge accurately represents reality—and it is true—or it does not, and is thus rejected. Subjectivity, on the other hand, relates to mere personal opinions (preferences, values, interests) and can never yield reliable knowledge. It is this strict ontological division between the non-human object and the human subject and its corresponding epistemology of represented facts and values (representationalism) that Latour has called the "Modern Constitution" (Latour 1993, pp. 13–15). The political order of the Modern Constitution now takes the form of an arena with two adversaries: the first one, called "science" and armed with powerful, but unconcerned facts taking all of the important decisions, and the other, called "politics," left with nothing but values, full of concern but quite powerless (Latour 1998, p. 104). The ideal of rational decision-making boils down to an ideal of irresponsibility: science dismisses politics of taking decisions. Science cuts politics short.

Attempts to counter this objectivistic dogmatism in epistemological as well as in political thinking have always reasoned from within this mutually exclusive fact-value framework of the Modern Constitution. As one of the most prominent critics of this "objectivism" in the representational epistemology of the Modern Constitution, social constructivism has concentrated on the sociological history of scientific knowledge production. As already argued however, any effort to thematise the subjective embeddedness of objectivity comes too late once the dissociation of subjectivity and objectivity has been (conceptually) established (see 1.c.1. On technological mediation and co-constitution). Any *a posteriori* conceptualization of subjective perspectives or social contexts inevitably leads to a threatening of the objectivity at stake, and gives rise to relativism. A similar evolution can be observed in political thinking, especially in the context of sustainability. Starting from the idea that sustainability governance is emerging as an increasingly scientised and technocratic domain, increased citizen deliberation and participation in the scientific realm have been proposed to reverse these technocratic features. A call for increased citizen participation was also strongly voiced at the 2002 Earth Summit in Johannesburg. Recognizing uncertainty and value-ladenness as elementary characteristics of sustainability problems, new forms of developing sustainability policies through broadened public participation have been proposed. Post-normal science (Funtowicz et al 1993) and sustainability science (Kates et al 2001) are, besides others, terms used to indicate a transition towards a new method for dealing with increased uncertainty in complex sustainability issues by "re-injecting" norms and values into scientific practice. Thinking from within the Modern Constitution however, making room for subjectivity by promoting public influence on conventional rational decision-making processes can only be thought of as a threatening of the objectivity at stake. Just as the reduction of the situatedness of scientific activity to contextual aspects such as values, interests, and concerns does not do right to the truly constitutive and normative aspect of a scientific paradigm, so do participatory approaches attempting to bring values "back into science" easily lead to a marginalisation of lay perspectives (Wynne 1996). At best, this "re-injection" of norms and values into scientific practice results in a negotiated sorting out of competing interests with scientific truth as ultimate executioner. Here participation merely serves to secure the legitimacy and acceptability of the decisions taken.

In the foregoing, I have tried to make clear that neither fact-centred technocratic nor value-centred participatory approaches yield the space for engaged decisions and responsible action towards more sustainable societies. Moreover, any approach that thinks from within the Modern Constitution is bound to end up as a symptomatic affirmation of science's hegemony. A crucial point in getting beyond the fact-value dichotomy of the Modern Constitution is to see how this one-dimensional discussion leaves the scientific questions, i.e., the way science frames environmental problems and solutions, unquestioned. In the next paragraph, I revert to my concept of topical truth, introduced in the context of nuclear physics practice, to open up a space of thought where the questions of science, rather than its answers, can be questioned and where science and politics no longer have to be seen as mutually exclusive.

2b. Topical Truth and the Politics of Engaged Knowledge

Extending the idea of co-constitution and its related conception of science as a necessarily situated and engaged activity beyond the boundaries of the nuclear laboratory now opens up a conceptual space where simplistic demarcations between science and politics, facts and values, knowledge and power can be critically assessed and challenged. By introducing the concept of topical truth, I aim to lighten up the normative entanglement between the sedimentations of co-constitution, rather than always already falling back to either of both sides. As the world and its problems do not present themselves in scientific facts, an important starting point is to see how matters of concern are—through science—always already framed into matters of fact.[9] According to the co-constitution view, scientific matters of fact such as CO_2-concentrations or viruses are the objective sedimentations of a subjective (i.e., scientific) engagement, while subjectivity (e.g., the scientific norms and preferences) comes into being only as the engagement of that sedimentation. As illustrated by my experience in the nuclear laboratory, this co-constitution process involves, of necessity, implicit matters of judgment, priority, choice, and interpretation as the necessary conditions of the objective sedimentation, the latter often embodied in explicit paradigmatic scientific procedures of abstraction and standardization. This scientific framing results in a model of the system of interest couched in terms of "matters of fact." In the Modern Constitution, this model is disconnected from its genesis and its validity gets a universal status: it is regarded as a true representation of the problem at stake and serves as the only valid basis possible for policy-making. This disconnection, however, blinds us for the inherent normative, i.e., topical, dimension of scientific practice. Considered in the context of its construction, a model aims to fulfil a certain function, and the choice of function depends on what kind of knowledge is aimed at and what the model is supposed to account for and to take into account: a problem is not chosen or given, it is formulated, framed, given shape (Peschard 2007). Latour provides us with the notion of "circulating reference" to emphasize the aspects of reduction and amplification involved in such a scientific framing process: the representational view of the world conveyed by such models renounces many of the key attributes of the original context, such as materiality, particularity and locality (reduction), while at the same time amplifying key attributes of "matters of fact" such as compatibility, standardization and text (Latour 1999, pp. 24–79).

Rather than conceiving of knowledge in terms of representations of the

9. In contrasting "matters of concern" with "matters of fact," I gratefully borrow from Latour's terminology (Latour 2004b). As I have mentioned in the Preamble, this paper tries to follow up on Latour's plea for repositioning the enigma of scientific production at the core of political ecology. In this respect, Latour himself claims that "matters of fact" should become "matters of concern" again. The other way around, I try to argue here that "matters of concern" are—in our scientific culture—always already framed in "matters of fact." Through the concept of topical truth I aim to lay bare the non-neutral, "political" ways in which this framing takes place, which, in turn, opens up the possibility of reforming this political dimension of "knowledge in the making." I thus try to find a way in which "matters of concern," although never given as such, can be adequately framed as such, i.e., as "matters of concern."

(social or material) world, the co-constitution perspective and its concept of engaged knowledge now emphasizes the socio-material practices from and within which these representations arise.[10] Such a view then also changes the way we think about ourselves and our place in the world in fundamental ways: the world now becomes something that we are embedded in and part of rather than being detached from and merely observers of, as representationalism suggests. Whereas the latter tends to paint the "natural world" as an enduring material backdrop to and constraint on our activities, the concept of engaged knowledge, recognizing the complex ways in which our practices shape the world, reveals the many potential configurations it may take, dependent on our topical choices and the practices to which these give rise. An epistemology of engaged knowledge, developed along the lines sketched above, thus makes convincingly clear how the practice of producing and applying knowledge has an inherent political dimension or how, as Jasanoff phrases it, "natural and social order are co-produced" (Jasanoff 2004). It lays bare for instance how the scientific calculations that allow us to shortcut politics are done at the cost of ignoring all of the externalities that fall out of view of the scientific paradigm (Goeminne and et al forthcoming) or how, the other way around, a new framing of an issue may reconnect certain externalities that were shortcut in a former analysis. The latter is illustrated by three subsequent contributions on resource consumption I co-authored for the annual peer-reviewed Environmental Report for Flanders, an important basic document for Flemish environmental policy (De Ridder et al 2002; Gerlo et al 2003; Gerlo et al 2004). Here, we shifted focus away from a classical, local "end-of-pipe" scope on environmental problems (acidification, erosion, etc.) to a more integrated assessment in terms of material flows calling attention to burden shifting and adding an international equity dimension to national environmental policy. It is here that my current research hypothesis on knowledge production as having an inherent political dimension initially took shape: the way our approach framed environmental

10. With respect to my reliance on Ihde and his "praxis philosophy" in understanding the practice of experimental physics (Ihde 1991), Joseph Rouse's work on practice theory constitutes an important reference in further elaborating on the normative dimension of "science in the making" (See Rouse 2002 and Rouse 1996). In developing a "normative" conception of (scientific) practices as constituted by the mutual accountability of their performances (Rouse, 2007), Rouse understands normativity in terms of accountability to what is at issue and at stake in a practice. Although I touch upon this connection with Rouse further on, I elaborate in more detail in Goeminne (forthcoming) on the parallels that can be drawn between the concept of topical truth and Rouse's conception of normativity.

issues in terms of equity and burden shifting was decisive for the possibilities that were opened up in terms of policy-making.

A crucial step now, which I can only begin to explore here, consists in employing the insights derived from the non-representational account of engaged knowledge in the elaboration of the institutional contours to facilitate social change for sustainability. A full appreciation of how knowledge acts to shape the world in ways that both enable and constrain choice over the futures available gives us two inherently related starting points: one related to the issue of participation, the other related to the concept of topical truth and its concern with the questions of science. Firstly, it has already been argued how the Modern Constitution acts to obscure how collaborations between scientists and non-scientists, by categorising the latter's practical and behavioural insights as mere preferences or values, might put lay insights at work in adequately addressing sustainability issues. Therefore, if sustainability is to be about human choice, and thus about the different practices and behaviours such choices embody rather than about specific technological options and trajectories, then engaging lay people in these terms in addressing the problem at stake is an imperative (Healy 2004, 200). The second starting point builds on the insight that the major concern of representationalism, its vain attempts to increase citizen participation in the scientific realm, and is focused on the justification of the answers science provides, that is, on the efficacy of whichever material or social factors are regarded as legitimating the representation of concern. Of primary concern to the practice-focused account of engaged knowledge provided here, however, is rather an enduring concern with the questions science poses and with matters of adequacy and relevance. Inspired by the concept of topical truth, true political questions now take centre stage: What is at issue? To whom and to what does it matter? and How can it appropriately and adequately be described? (Goemine and François 2010, pp. 119–123).

Building on these two starting points, I suggest the term "engaged participation" to denote this form of participation that on the one hand facilitates collective understandings, embodying a diversity of insights, and on the other hand, is reflexively occupied with the topical question. In my account of objectivity, lay knowledge is genuinely integrated, not by categorizing it as mere values or preferences and in this way paralyzing them, but by focusing on their role in the "in-between" of the constitution of objectivity. Analogously, expert knowledge is no longer paralyzed as matters of fact by granting them an absolute status. Both expert and lay knowledge are allowed to participate in addressing relevant issues and what connects them is an enduring concern with the topical question.

Here, participation gets a different—"engaged"—status. Engaged knowledge practitioners, lay and expert, participate in the same practice in that what they do or say is accountable to a measure constituted from within, in the dynamics of practice, in response to what they recognize as what is at issue in the practice. As opposed to the image of the arena, as the political order of the Modern Constitution where paralyzed facts fight and win over paralyzed values due to the superiority of the former in our scientific culture, I propose the image of the agora as the political order of the co-constitution ontology. In its broadest sense, an agora, referring to the central place in ancient Greek cities where genuine discussion took place, denotes a "working space" where engaged participation is made possible: the agora is constituted as the place where lay and expert knowledge are on equal footing through their common accountability to the measure of topical truth.

As an illustration of what form such a science-policy agora may take, I want to refer to a highly unconventional research project I have been involved in at the Centre for Sustainable Development and which has inspired me in conceiving of "engaged participation." Funded by the 2003 Policy Preparation Research Programme of the Flemish Interuniversity Council this project aimed at clarifying the concept of "ecological debt" and studying its relevance and applicability in Belgian and international policy.[11] Application should be understood here as an attempt at formulating policy guidelines to address ecological debt nationally and in an international context of UN negotiations, as well as an attempt at quantifying part of Belgium's ecological debt for the energy/climate theme and the agriculture/food supply theme. With respect to other sustainability concepts such as "ecological footprint" (see, e.g., Wackernagel et al 1996) and "environmental utilisation space" (see, e.g., Opschoor et al 1994) which have been developed in a scientific context, ecological debt is quite unique in the sense that it is a grassroots concept, mainly developed in a campaigning context by NGO's in 'developing' and 'less developed' countries. Within the research project, we tried to stay as close as possible to the original meanings and interpretations of ecological debt, such as had been developed in the campaigns. Therefore, we combined a truly multidisciplinary team of legal, agricultural, economic and political experts with a participative approach engaging Southern NGO representatives in discussion and exchange moments. In this way, it became clear to us that ecological debt, rather than being a scientific concept, should be regarded as a

11. For an extensive report on this research project, the reader is referred to Paredis et al 2009.

lens through which international relations and sustainable development policies are seen in a new light, namely from a Southern peoples' point of view. Through ecological debt, the interpretation of sustainable development is enriched with typical environmental justice characteristics: an analysis of power relations and patterns that reproduce existing inequalities is added, with questions such as "who gets what, how much and why?"; a rights discourse is added, where the right to a clean and safe environment is defined as a human right; and a grassroots perspective is added with a shift in perspective away from abstract sustainable development policies to the lives and problems of "real people in real places." Most of the scientific articles elaborating on ecological debt so far however, are qualified by an attempt to narrow down the concept of ecological debt, with its richness of non-scientific perspectives mentioned above, into a merely scientific one. In the best of scientific traditions, thrusting aside a reflexive conceptual discussion, these elaborations rush forward to objectification: ecological debt is provided with a uniform definition that allows for a uniform calculation and valuation method. A clear example of this can be found in a recent paper on ecological debt where the latter is straightforwardly defined in quantitative terms as "the environmental costs of human activities over 1961–2000 in six major categories" (Srinivasan et al 2007, 1768). In this way, the paradigm of ecological debt, organically grown from and intertwined with the lives and problems of "real people in real places" is irreflexively appropriated by a scientific-economic paradigm ruining the enriching ethical-political perspectives the concept has to offer. Moreover such an approach inscribes itself in a deterministic process of rational decision-making cutting politics short at the cost of ignoring all of the externalities that are brought to the forefront in the original enriching ecological debt discourse. Eventually, this short-circuiting leaves no room for real political, i.e., topical choices towards structural change.

Although we did also focus on quantifying aspects of ecological debt, it was precisely what can retrospectively be viewed as an "engaged participation" approach that guaranteed we did not slide off in a straightforward quantification effort. In our search for a working definition, for instance, we would come up with a preliminary version, which typically provoked some resistance from the NGO-voices involved in the project. From this, we tried to accommodate their concerns and reactions and would come up with a revised definition. And this went back and forth a few times. In this way we were constantly forced to rethink our own approach, guaranteeing a more reflexive way of framing the issue at stake. In this way, our research distilled two core elements in the meaning of ecological debt, i.e., "causing ecological damage elsewhere" and "using ecosystem goods and services at the expense of equitable rights of others" which formed the basis for our working definition. Here, the broadly interpretable term "equitable" was purposively used instead of an already objectified interpretation of what equitable should mean (e.g., equal). In using the term equitable we tried to accommodate different concerns voiced in the original ecological debt approaches such as those about indigenous knowledge and subsistence rights. In this way, we deliberately did not shortcut politics by settling the ecological debt issue once and for all by reducing it to a mere number.[12] Rather, we kept the ecological debt concept where it originated and where it belongs: in the scientific-political agora, on the interface between science and politics, neither reduced to a factual nor to a value discourse. I thus suggest topical truth as a conceptual instrument to avoid the taken-for-granted scientific shortcutting of politics. In deliberating policy decisions, the accent then no longer lies on a negotiated sorting out of competing interests with scientific truth as ultimate executioner; rather the topical foundation of a decision has to be questioned.

Concluding Remarks

This paper is highly ambitious, but necessarily so. Conceived as the history of my topics of interest in the politics of sustainability, it bridges the worlds of science and sustainability beyond the taken for granted but baleful policy ideal of rational decision-making. This paper does not pretend to be a full-blown theoretical framework for a politics of sustainability, nor is it a fully-fledged epistemology of scientific practice. Rather, its main value is to be found in the strength of the argument for repositioning the enigma of scientific production at the core of a genuine politics of sustainability as Latour has pleaded for. Here, this argumentation has been developed on two highly intertwined levels. First of all, on the level of my personal history, I have shown how the reflexive questions I had posed about the epistemological and ontological status of scientific knowledge when I was producing facts in the nuclear laboratory are of crucial importance and relevance when investigating the role of scientific knowledge in the political organization of society. Secondly, on a more general and conceptual level, I have sketched how a politics of sustainability, developed around the concept of "engaged participation," might instruct a more fruitful approach beyond the fact-value dichotomy of the Modern Constitution.

12. For a more detailed, reflexive discussion of the unconventional aspects of this research project in relation to the concept of topical truth, the reader is referred to Goeminne et al forthcoming.

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