Controversial valuations. Assembling environmental concerns and economic worth in clean-tech markets

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Introduction

Environmental concerns are increasingly seen as not only raising a threat to which firms need to adapt by becoming "greener" and more "socially responsible", but also as offering opportunities for new business development. Instead of being relinquished to the status of externalities, which firms more or less willingly come to internalize, environmental qualities (or deficiencies) now sometimes happen to be brought to the center of the calculation of the value of new products. The emergence of a "clean-tech" sector epitomizes this move towards the economization (Callon and Caliskan 2009) of concerns which have hitherto been considered as lying outside of the market. This paper proposes to investigate the construction of clean-tech markets by examining the mechanisms through which new technologies succeed (or fail) to be transformed into goods which possess a twofold value: environmental quality (their "cleanliness") and economic worth (their price).

The examination of this question has usually been torn apart between two distinct theoretical approaches: economics has explained how the prices of goods are formed, while economic sociology has demonstrated how the qualities of goods are shaped by institutions, conventions, and social networks (Smelser and Swedberg 2005; Fligstein 2001; Granovetter 1985). Focusing on prices, economics has implicitly assumed that the qualities of goods are stabilized; focusing on qualities, sociology has tended to overlook how economic agents quantify, calculate prices, and come to agree on them (Beunza and Garud 2007; Callon 1998b). Following a novel stream of research on the pragmatics of valuation which abandons this separation, and instead embraces numbers, and prices in particular, within its scope of analysis (Espeland and Stevens 2008; Muniesa 2007), this paper adopts the following assumption: the clean qualities of a product and its price are not pre-given, sequentially determined, or imposed by external forces such as markets or institutions, but simultaneously constructed by the various actors who participate in the innovation process. By studying these construction processes, we envisage the problem of valuation (Dewey 1939) through the lens of practice, casting the definition and worth of cleanliness as the product of situations rife with uncertainty (Stark 2009).

The paper proposes a case study focusing on a Danish new venture that has developed solutions for handling manure in agriculture[1]. These solutions are "clean-tech" in the sense that they reduce ammonia and odor emissions from farms. We observe how cleanliness is *qualified* and *priced* in this case by following the entrepreneurs' struggle to demonstrate that their products are beneficial to the environment and to the farmer as well; that they are both environmentally sustainable and economically worth. While (un)cleanliness has long been considered as an externality (i.e., a quality of goods that is not to be taken into account in the calculation of their price, but to be tackled as a matter of political intervention or user awareness for example), clean-tech entrepreneurs endeavor to move this quality within the boundaries, and to the core of, economic calculation. This move is not straightforward. While in settings like carbon markets the metrics of cleanliness (defined as the quantity of CO_2 emissions) have been purposefully designed and implemented, the qualities and the prices of would-be clean technologies, as well as the instruments to measure them, are in the making. Thus, clean-tech entrepreneurs embark on an innovation journey that deals with the

[1] We are grateful to Zeinab Al-Asfoor and Roman Graber, who devoted their master thesis to this case study, for their help with data collection and for the insightful discussions we had at Copenhagen Business School and during field trips, in which emerged many of the ideas developed in this paper.

exploration not only of new technologies, but also of heterogeneous (technical, economic, social) – and, as we will see, contested, values.

Markets inside the ecological revolution[2]

What is the place of markets within what some have described as an "ecological revolution"? How do firms deal with it? Three different types of answers can be identified in the management literature. First, in the tradition of "issue management" (Ansoff 1980), corporations have tended to consider the rise of environmental concerns as a potential threat to which they should react. Endeavors to prevent or respond to (expected) contestation have resulted in the implementation of "corporate social responsibility" (CSR) programs and other "non-market strategies" (Baron and Diermeier 2007; Baron 2010). While such practices and their scholarly analysis emphasize the embeddedness of economic activities in the social (Granovetter 1985), they perpetuate a firm distinction between the former and the latter. In this perspective, the environmental externalities of economic activities are acknowledged, but kept outside of the market and of companies' core business. For example, governments impose taxes so that firms internalize the externalities that they produce (the term "internalization" is misleading though, because it reinforces the idea that the environment *is* "external" to economic activity); the corporations that implement social responsibility programs delegate them to a distinct department and account for them in a separate annual report.

However, attempts to reconcile and entangle market and environmental logics have emerged. Management scholars, for example, have engaged into debates on whether "it pays to be green" (King and Lenox 2001). Economists have been involved in studying and designing markets in which environmental externalities, i.e. CO_2 emissions, are made tradable. Such attempts investigate, and experiment with, the translation of environmental into economic value. Nevertheless, they appear to leave unquestioned the starting point of the translation (how certain goods come to acquire an environmental value) and its instruments (pre-defined indicators and mechanisms, such as profitability and price, are generally used). In this perspective, externalities are genuinely internalized; however, they are not normalized: translation operations appear as exceptional and "regular" calculative frames remain unchanged.

The emergence of a "clean-tech" market is interesting in this respect, as it blurs the boundary between economic and environmental value. Here, environmental qualities are brought to the center of the calculation of new products' worth. A new perspective then opens up, in which environmental concerns are neither seen as a threat, nor addressed within the boundaries of idiosyncratic corporate and market spaces (such as CSR departments and carbon markets). Environmental concerns, the promoters of clean-tech entrepreneurship argue, provide "regular" economic actors (start-ups and incumbent firms as well) with new opportunities ready to be exploited.

The existence of such *clean-tech opportunities* is problematic, though. While there certainly is a demand for cleaner goods, the qualities of products which are unfriendly to (or simply ignore) the environment are already deeply integrated in the market as habits of use and cost-efficiencies, as well as accepted in standards and regulations. Indeed, contrary to the neoclassical understanding of markets as impartial arenas for competition, new economic and sociological theories have depicted

[2] We borrow this phrase from the title of a sub-theme organized by Fabian Muniesa, Peter Karnøe and Petter Holm at the EGOS conference in June 2011.

markets as full of politics, because interests are inscribed in institutionalized metrics and rules (Fligstein 2001). The market no longer appears as a neutral mechanism for selecting the best products, because the criteria for what defines the best qualities are not independent and pre-existing, but become part of market structures in the historical process of their formation. This sheds light on the difficulties faced by clean products: they defy well established market mechanisms, because (part of) their value lies in what is framed as "external" to the market. Clean-tech entrepreneurs embark on an uncertain innovation journey that deals not only with exploring new technologies, but also with building new market spaces and new value metrics. The following question then arises: how can there be any entrepreneurial opportunities at all in the clean-tech market?

Clean-tech opportunities, networks and valuation

In the literature, entrepreneurship has classically been analyzed as the encounter between individuals and opportunities (Venkataraman 1997; Shane and Venkataraman 2000). Recently, discussions have emerged as to the origin of entrepreneurial opportunities, contrasting "discovery" and "creation" theories (Alvarez and Barney 2007). The former, albeit prevalent in the entrepreneurship literature, are of little help when it comes to clean-tech opportunities. Indeed, they depict opportunities as something which *exists* out-there, in the market, in the form of price discrepancies or unsatisfied customer needs. The problem with clean-tech opportunities, to put it bluntly, is that they do not exist, because the value of clean products falls out of established calculative frames; it lies in what is supposed to be external to the market.

The alternative approach, which analyzes opportunities as the result of a collective and experimental processes of construction (Garud and Karnoe 2003; Shah and Tripsas 2007; Baker and Nelson 2005; Doganova 2009), appears then more appropriate in the case of clean-tech markets. It is worth emphasizing that the label "creation theory" is misleading. While some critiques of dominant discovery theories of entrepreneurial action have tended to depict opportunities as the pure product of entrepreneurs' creative minds and of the conviction power of their discursive stratagems, this is not what we mean by opportunity construction here. Our objective is to take seriously the construction work performed by entrepreneurs; to problematize the existence of clean-tech opportunities, without reducing markets to politics. In order to do so, we build on two lines of research.

First, taking inspiration from innovation studies, we examine clean-tech entrepreneurship as a process of building socio-technical networks. The literature has indeed emphasized the distribution of innovation across various actors, such as customers, users, technological or commercial partners, investors, and regulators, whom the entrepreneur must enroll in order to innovate successfully (Bijker and Law 1992; Chesbrough 2003; Garud and Karnoe 2003; Teece 1986; von Hippel 1976). The enrolment of allies results from the work of "interessement" (Akrich, Callon, and Latour 2002) which consists in operations of translation (Latour 1987) and demonstration (Rosental 2007; Stark and Paravel 2008). These operations are material, in the sense that they are equipped with various tools (Beunza and Stark 2004; Callon, Millo, and Muniesa 2007; Doganova and Eyquem-Renault 2009). Building on this line of research, we analyze clean-tech entrepreneurship as a distributed and instrumented process through which proposed environmental and economic values are put on trial, experimented, contested, negotiated, and gradually stabilized (Latour 1987).

Second, we take inspiration from a novel stream of research on the pragmatics of valuation which brings together the study of (economic) value and (social) values (Stark 2009), of the nominal and numeric scales of valuation (Guyer 2004), of the emotional activity of praising and the rational endeavor of pricing (Dewey 1939). In this perspective, valuation is envisaged as a process of inquiry and experimentation (Dewey 1922) through which new economic entities are gradually provided – instead of initially endowed - with a set of qualities (Callon, Méadel, and Rabeharisoa 2002), among which their cleanliness and their price. This approach seems well suited to the study of clean-tech, whose definition and worth are contested and in the making. It impedes restricting attention to one of the dimensions of valuation – by reducing cleanliness to a socially constructed quality or to a price premium determined by the natural encounter of supply and demand - and assuming that the other dimension is set and unproblematic.

In our view, the problem of valuation lies at the heart of clean-tech entrepreneurship. Empirically, one of the main challenges faced by innovators in this field is to demonstrate the value of clean products in a "hostile territory" (Karnoe 2010). Theoretically, the ambivalence of the concept of valuation echoes that of clean technologies: referring both to the activity of prizing (i.e., holding precious, dear) and appraising (i.e., putting a value upon an object), the term allows seizing both environmental and economic qualities, describing both cleanliness and price. Emphasizing valuation as a relational process, which is triggered by "problematic situations" and characterized by the experimentation of ends and means, Dewey's (1939) analysis suggests investigating the collective construction of environmental and economic values by entrepreneurs and others, instead of leaving it to the market to reveal, or to politics to decide.

Methodology

Our empirical site is the corporate venturing unit of a leading Danish pump manufacturer. The mission of this recently created department (which we will call *NewBiz*)[3] consists in identifying, selecting, and investing in clean-tech innovation projects. The projects vary in their content (e.g., solutions for pressure measurement, for animal production, for wastewater treatment, for water supply in poor regions), their degree of development, their origin (internal or external), and their focus (technological or business model innovation). What they have in common, as *NewBiz* puts it, is their location in the clean-tech field.

We conduct an in-depth case study (Eisenhardt 1989; Yin 2003) of one of these clean-tech innovation projects (which we will call *CleanFarm*). *CleanFarm* is a new venture that offers solutions for handling manure in agriculture. *NewBiz* invested in this start-up in 2004 and subsequently became its unique shareholder. At the time of investing, *CleanFarm* was starting to commercialize a slurry acidification system (herein called *AntiAmmonia*) that allowed decreasing ammonia emissions from pig and cattle farms. Since then, the company has developed a second product (herein called *AntiSmell*): an ozone-based slurry treatment system that reduces odor nuisances. We follow the evolution of these two products since their conception and we describe how *CleanFarm* has continuously attempted to demonstrate their environmental and economic value to a wide array of partners, some of whom happened to oppose fierce resistance to the entrepreneurs' enrolment endeavors and calculations of worth.

[3] For confidentiality reasons, the names of people, organizations, products, and technologies have been replaced by fictitious names.

The case study uses two sources of data: interviews and document analysis. We have conducted interviews with the members of *NewBiz*, with managers from *CleanFarm* (managing director, R&D manager, technical manager, sales manager), and with *CleanFram*'s stakeholders (customer farmers, a farmers' association, the Ministry of the environment, a scientist, a NGO, and a competitor). We have been given access to a wide range of internal corporate documents relating to the *CleanFarm* project, including board meetings minutes, business plans, Powerpoint presentations and status reports. In addition, we have collected public data relating to *CleanFarm* and, more generally, to the political, legal and technical aspects of ammonia and odor emissions reduction (e.g., legislation, standards, scientific papers, reports and press releases). The quotations used in the remainder of the paper come from these interviews and documents.

Case study

What does a farm produce? Certainly, a pig farm, for example, produces meat. But this is not all. In addition to the trucks full of animals heading for the slaughterhouse, a pig farm lets out a number of other entities which economists would call "externalities". Externalities take different forms. For neighbors, they are to be found in the unpleasant smell which dwells in the farm's surroundings. For environmentalists, they lie in the ammonia emissions which evaporate from animal waste into the atmosphere. While such undesirable effects have long been part of the production process that transforms animals into the meat that we purchase and consume, they have recently turned into growing "matters of concern" (Latour 2004). Neighbors and environmentalists have been joined by other actors. Consumers have become increasingly aware of the invisible costs at which food is made available to them. Government has implemented regulation that attempts to limit the damage made to the environment by intensive agriculture. More recently, a new type of actor has raised its voice: firms have taken a stake in the "cleaning" of agriculture. Some have envisaged the concerns of neighbors, environmentalists, consumers and government as an opportunity for profit. In their view, clean technologies, which would alleviate the negative externalities of agricultural production, bear the potential to provide both environmental *and* economic value. In other words, smell and ammonia emissions have come to be seen not only as matters of concern, but also as *matters of worth*. It is to such a transformation of matters of concern into matters of worth that the start-up *CleanFarm* buckled down in 2005.

In the nexus of technologies and issues

The ammonia and odor emissions of agriculture stem from animal waste. As animals – pigs, for example - are fed, they produce feces and urine, which form the manure (or slurry) that farmers collect and use as fertilizer. The handling of slurry involves three steps: animal waste continuously gathers in the slurry pits beneath the slatted floors on which pigs spend their short lives squeezed into farm buildings; on a regular basis, the accumulated slurry is pumped into outside storage tanks; at particular times of the year, it is taken from the storage tanks and spread in the farm's fields where it serves as fertilizer thanks to the organic matter and nutrients, such as nitrogen, that it contains. As this process unfolds, ammonia evaporates into the atmosphere from the slurry pits, the storage tanks and the fields. This raises two main issues. The first one has to do with odor. The second one has to do with the ecological consequences of ammonia emissions: the ammonia emitted in the air contributes to the formation of acid rains; falling back onto the earth, nitrogen can have a damaging impact on ecosystems and biodiversity. As explained by an NGO that we interviewed:

"Ammonium is a big problem for eco-systems in Denmark. We have many vulnerable eco-systems which are dependent on low levels of nitrogen and therefore the large ammonium evaporation from animals in Danish farms is a threat to these eco-systems. Here in [our NGO], we have proposed that ammonium emission to be reduced by 50 % in 2020 compared to today. (…) Recently it turned out that there is another problem with ammonia, which is that it contributes to pollutants and particles. [There was] a report from the Danish Environmental Research Institute saying that ammonia [from agriculture] combines with sulfate from other sources, especially from ships; this form ammonia-sulfate, which occurs as particles, and these particles are hazardous to human health."

Ammonia emissions are now "an internationally recognized problem" and political action has been taken in order to reduce them. In particular, the IPPC (Integrated Pollution Prevention and Control) directive in the European Union has included agriculture (which is said to account for about 75% of total ammonia emissions) into its scope, calling for EU member states to implement measures in order to curb the ammonia emissions related to animal production.

It is in this context of increased public attention to the "slurry issue" and the "smell issue" in agriculture that *CleanFarm*'s founders encountered two technologies, which appeared to address the concerns raised by government, environmentalists, and famers' neighbors. The first technology, which we will call *AntiAmmonia* here, relied on the following principle: if acid is injected into the slurry accumulated in the pits underneath slatted floors, the slurry's pH value decreases, which reduces ammonia emissions. The second technology, which we will call *AntiSmell* here, claimed that the use of ozone and UV rays to clean the air in the stables could reduce odor emissions. While *AntiSmell* was still in an early stage of development, *AntiAmmonia* had already been installed in about twenty farms in Denmark; yet, the installed systems did not seem to "work" well enough and some customers were complaining. *CleanFarm*'s founders decided to purchase the assets of these two technologies, with the objective to combine them in a future integrated solution that would allow farmers to get rid of the growing complaints about their ammonia and odor emissions.

If they managed to deliver their promises, these two technologies, the entrepreneurs thought, would be endowed with immediate value, for they answered clearly articulated issues, associated with clearly identified concerned groups (Callon and Rabeharisoa 2008). For *AntiSmell*, those were the neighbors who suffered from the unpleasant odors freed from nearby farms. Even though a few protests were taking place here and there, there was no collective action led by farmers' neighbors. The entrepreneurs thought they could contribute to giving birth to such action, while raising public awareness about the issue of smell:

"We need to make it "socially unacceptable" for farmers to continue to produce so much smell. That is to say, to make the farmer's wife feel uncomfortable when she goes to the shop in the village. We have been thinking about this and have some ideas. We can place ads in the magazines read by people who live in the countryside, and especially women. We already have some stories in mind. For example, a man who goes to the doctor and says that he can't smell anymore – it's not a problem with your nose, says the doctor, the farmer is using [AntiSmell] now!"

That would transform individual concerns – sporadically expressed by all those who happen to live or just pass by a farm – into a collective concern, thereby providing an odor-removing technology such as *AntiSmell* with an obvious value for its targeted customers, i.e. farmers.

The issue of ammonia emissions, by contrast, was already embedded in structured collective action, in which government played a central part. The legislation implemented in the wake of the European IPCC directive required that every farmer who wished to expand her facilities or build a new farm obtained an "environmental permit". To obtain such a permit, the farmer had to demonstrate to the municipality that the ammonia emissions of the expanded or new farm would be reduced through the use of appropriate technology, such as the *AntiAmmonia* acidification system. Certainly, ammonia emissions reduction was not as "sexy" an issue as smell or CO_2:

"[Smell is] much more sexy. (…) [With ammonia emissions, the neighbors] cannot tell. They will not be able to see the effects. They cannot see all the difference. (…) So smell is much better, because you can immediately tell. (…) Our Minister of the environment, she is trying to launch a campaign now for biodiversity. And I think she will have a hell of a job, because it is not sexy, it is not. You cannot see it. It is not an overnight [change]. (…) It is not even like CO_2 where you have global warming, you have pictures of glaciers disappearing… This is very intangible, you can hardly see it. You need a biologist to go out into a field with a period of 10 years in between and then he can say that over ten year time, the biodiversity has decreased by 50% or whatever. It is a very hard message to sell."

Even if the ammonia emissions issue was less appealing, the facts spoke for themselves: any farmer who wished to expand her facilities, had to obtain an environmental permit, and for that, she needed to implement a technology that was approved as reducing ammonia emissions (and regulation was expected to get even stricter in the next years). It appeared then that all *CleanFram* had to do was to make these facts harder and inscribe *AntiAmmonia* within them. The entrepreneurs' fact-making strategy relied on putting politics and science "on their side": mobilize government, to ensure that environmental regulation is passed on and complied with, and mobilize universities, to ensure that the decrease of ammonia emissions enabled by the *AntiAmmonia* technology was documented and backed up with undisputable evidence.

From matters of concern to matters of fact

The government mobilization axis of *CleanFarm*'s fact-making strategy involved a series of presentations and discussions with the Danish parliament and its Environment committee, with the Ministry of the environment, and at the European commission. The entrepreneurs' "elevator pitch" was simple: given the decrease in emissions enabled by the slurry acidification technology, getting the ten biggest pig producers in Denmark equipped with *AntiAmmonia* would enable the government to achieve the level of ammonia emissions reduction that it had committed to. *CleanFarm*'s strategy aimed at "planting visions and ideas at central places". These central places included ministries and parliament, but also other stakeholders such as farmers' associations and NGOs active in the field of environmental protection. The objective was not only to push for tighter regulation, which rumors said was forthcoming, but also to promote the vision that "slurry is value-streams, instead of problem-streams".

Even though it cannot be said to what extent that was a result of *CleanFarm*'s "planting" efforts, the message was spreading and the handling of manure was becoming a growing issue, as we can see in the following quote by a MP spokesperson for the environment:

"In Denmark there are about 1.000 plants that purify wastewater from humans. Conversely, the manure from 26 million pigs is not cleaned, but poured directly into the fields, to the detriment of nature, Danish drinking water, lakes, estuaries, etc. and the thousands of people who have to live in

the midst of odor. For the protection of the Danish common resource, water, and for environmental reasons, the Social Democrats say that the extensive spread of manure on fields and in nature must stop within about 10 years. (…) Agriculture has now maximum 10 years to achieve, in collaboration with researchers in the private and the public sector, the further development of the technologies necessary to put an end to the spread of untreated manure on fields. In addition to significant environmental benefits, removing odor and improving the overall image of agriculture, there are also huge export opportunities in such slurry technologies."

The second axis of *CleanFarm*'s fact-making strategy consisted in demonstrating the causal relationship between its slurry acidification technology and ammonia emissions reduction, in order to quantify the environmental benefits of *AntiAmmonia*. In this respect, academia appeared as a significant ally. Since the 1990s, several studies had proved the impact of acidification on ammonia emission, using laboratory experiments, field tests and modeling techniques. There was still significant uncertainty, however, due to the complexity of the measurement of ammonia emissions and to the wide range of factors that are likely to affect the level of emissions. Several farm tests were conducted in collaboration with agricultural scientists and the farmers' association. For example, in 2004 a test on a total of 1.200 animal units split into four sections (out of which two control groups) concluded that the slurry acidification method reduced ammonia emissions by 70%. *AntiAmmonia* was approved by the Danish Environmental Protection Agency and, in 2006, was included in the Best Available Technology (BAT) list[4]. By contrast, the tests conducted on the *AntiSmell* technology provided inconclusive results, and its commercialization was delayed due to the need for further research and development (consequently, in what follows we will focus on *AntiAmmonia*).

Getting on the "technology list" was a crucial step for *AntiAmonia*. It is on that list that municipalities, which are in charge of delivering environmental permits to farmers wishing to expand their farm or build a new one, rely in order to decide whether an application should be accepted or denied. The technology list is supposed to serve as a "guideline", but given the complexity of proving ammonia emissions reduction, it becomes a *de facto* standard: a farmer who implements one of the technologies approved on that list is sure to obtain a permit; conversely, going for a method that is not on the list and trying to prove its efficiency is a risky strategy, all the more as several NGOs monitor the attribution of permits and may file complaints. Because it provides data on the benefits and costs of each technology, the list is also used by farmers and their advisors in order to compare and choose which technology to implement. In other words, the list becomes the calculative space within which *AntiAmmonia* is ranked relative to substitute products and assessed by potential customers. It operates a "framing", by establishing a boundary between the quality of goods that will

[4] The Danish Environmental Agency's (EPA) website describes BAT as a list of technologies that have been analyzed with regard to their environmental performance. On the basis of the results of this analysis, presented in the so called "technology sheets", "the Danish EPA has conducted standardized BAT-assessments for the most prevailing combinations of types and sizes of livestock farms in Denmark. These BAT-conclusions include quantitative BAT-emission limit values for ammonia and phosphorous together with qualitative BAT-assessments for nitrate leaching and the consumption of water and energy. The emission limit values apply to the installation - in this case the farm - and it is left to the farmer to decide which techniques or technologies he wishes to apply on the installation in order to comply with these emission limit values." (http://www.mst.dk/English/Agriculture/environmental_technologies_agriculture/bat_best_available_techniques/)

be taken into account in the calculation of their worth, and those that will be left unconsidered (Callon 1998a), and it translates the former qualities in monetary terms.

"It is essential what it says on the Technology list. Nobody cares about the reality. Because you cannot measure it anyway. You cannot go out into a farm and say: 'Ok, I measure the ammonia content here, then I know if it works or if it doesn't work'. It is based on a test and it is based on an approval and then you do not go out and measure in the actual application. It is all based on the test. So when it says here: 'Floors [an alternative ammonia emissions reduction method, which consists in reducing the openings in the slatted floors in order to reduce the surface through which ammonia can evaporate from the slurry pits] have a 50% reduction', that is it. That is what it says, so if I buy this floor and I put it in, I have a 50% reduction. If I buy [an acidification] system, I have a 50% reduction, I do not have to test it. I do not need to measure it. So it is extremely important what is on this list and which reduction percentages are on it."

The technology list thus produces facts. The qualities considered and quantified in the list (by how much a given system reduces ammonia emissions and how much it costs) become reality. The reality in question is not one that would exist independently from the list and be objectively mirrored – this is why our respondent in the quotation above laments that "nobody cares about the reality" -, but one that is performed by the device and the calculative space that it establishes. However, as noted by Callon (1998a), any framing triggers overflowing. This is what happened in the case of *CleanFarm*: getting on the technology list was a double-edged sword, because, as we will see in the next section, no soon had the value of *AntiAmmonia* (i.e., its necessity, its performance and its cost) been turned into a freshly made fact that contestations started.

Controversies over numbers

Figure 1 reproduces a table from the technology list which presents the official estimates of the cost of *CleanFarm*'s slurry acidification system in cattle stables (the document chosen here refers to dairy farms). Similar tables exist for the other ammonia emissions reduction methods approved by the Environmental Protection Agency and included on the technology list. Let us examine the numbers in this table in further detail. As the cost of the system decreases with the size of the farm, the first column indicates the number of "animal units" for which the calculations are relevant. The second column indicates the additional cost, per cow cubicle, incurred by investing in the *AntiAmmonia* system. The third column indicates the additional cost per kilogram of meat, excluding the value of the savings on nitrogen (N) and sulfur (S) which the system allows for (the measure of these savings will be explained in further details below). Our respondents refer to this number as "the cost to the farmer". The forth column indicates the additional cost per kilogram of reduced nitrogen, excluding the value of the savings on nitrogen (N) and sulfur (S). This number is referred to as the "environmental cost": a number about which "the farmer does not care, but the authorities care". The fifth column indicates the value of the quantity of nitrogen and sulfur that the system allows the farmer to spare. The last two columns recalculate the additional cost per kilogram of meat and per kilogram of nitrogen reduced, including the value of the savings on nitrogen (N) and sulfur (S). For example, for a farmer who has 150 animal units (which correspond to about 120 cows), the cost of *CleanFarm*'s *AntiAmmonia* system will amount to 0.09 Danish krona per kilogram of meat produced (which corresponds to a 4% increase in costs due to the investment) if the value of the savings on nitrogen and sulfur is not taken into account; if this value is taken into account, the cost goes down to 0.06 krona (which corresponds to a 3% increase). In this case, a kilogram of nitrogen reduced costs 58 or 39 krona, depending on whether the value of savings is taken into account.

MILJØMINISTERIET

Miljøstyrelsen

Tabel 1: Skøn over økonomiske konsekvenser af gylleforsuring i kvægstalde med ringkanal og bagskylsanlæg sammenlignet med referencesystemet.

Svovlsyrebehandling af gyllen i stalde med drænet gulv	Merinvestering pr. sengebås	Samlet meromkostning pr. kg EKM ekskl. værdi af sparet N og S		Samlet meromkostning pr. kg N reduceret ekskl. værdi af sparet N	Værdi af ændret N og S indhold	Samlet meromkostning pr. kg EKM inkl. værdi af sparet N og S		Samlet meromkostning pr. kg N reduceret inkl. værdi af sparet N og S
Dyreenheder	kr.	kr.	i %	kr.	kr.	Kr.	i %	kr.
75	11.556	0,15	7	100	14.914	0,13	6	81
150	5.778	0,09	4	58	29.827	0,06	3	39
250	3.467	0,06	3	41	49.712	0,03	2	23
500	2.000	0,05	2	30	99.425	0,02	1	12
750	1.689	0,04	2	28	149.137	0,01	1	9
950	1.333	0,04	2	25	188.907	0,01	0	7

Beregningerne er foretaget på baggrund af nybyggeri til en produktion fra 75 til 950 DE. Økonomivurderingerne er baseret på producentoplysninger og skøn.

Figure 1. A table with cost estimates from the technology List

These numbers are extremely important. First of all, it is on their basis that the government decides whether it is "reasonable" and not too "expensive" to enforce regulation. The threshold is a matter of "political decision", explains a *CleanFarm* manager, and the numbers vary with the type of animal considered: for example, the additional cost incurred by investing in environmental technologies should not go beyond 2% of the production cost in the case of pigs, and 1% in the case of cows. If there are available technologies that allow reducing ammonia emissions at such a "reasonable" cost and hence regulation is enforced, farmers are required to implement these technologies if they are to obtain an environmental permit. They have to choose one of the technologies available, and it is once again on the basis of the numbers presented in the tables of the technology list that they make a decision. The cost of the system, as compared with other systems, becomes then a crucial parameter.

"I can of course internally from our company make a calculation anyway I like. But there is this official document that the farmers (…) look at. (…) What we need to do is that we need to make sure that this contains the right numbers, right? Because this is what everybody will be looking at and this is also what they compare."

Getting "the right numbers" is not straightforward, though. For example, controversies have arisen over the "real" cost of the *AntiAmmonia* system. In particular, the farmers' association has claimed that the maintenance cost of the system should be higher:

"We say that maintenance of one of our systems costs about 20.000 krona per year. The pig union tells the ministry that it costs 80.000 krona. Four times more expensive. (…) And you can say [that] maintenance is this much [and that] there is not much to argue about, but there is. We can document

that none of our customers has ever been more than 20.000 krona per year, but they claim it is 80.000 dkk. And then they have a big fight over what is the right way of looking at it. Should we have an all-in service agreement, [in which the farmer] can call [us] anytime, or should we say: 'well, whenever the farmer can, he fixes the things himself and if he can't do it anymore, we come and help'. And it is not the reality, it is not what the farmer in the end of the day is going to pay, it is a question of manipulating the numbers."

However, controversies over costs are not only about "manipulating the numbers". Let us take the example of the system's operational costs. Their major component is the cost of the sulfuric acid that the farmer has to add in the slurry in order to acidify it. The chemical reaction is supposed to require 5 kilos acid per ton of slurry produced, and the norm tells the average quantity of slurry produced by each type of animal, so the calculation should be simple. However, some of the farmers using the *AntiAmmonia* system started to complain that they use much more sulfuric acid than expected. *CleanFarm* has come up with the explanation that the norm figure is too low, and that actually animals produce more slurry than indicated:

"This calculation is based on the norm figure. If I now say this norm figure is wrong, (…) this means that all farmers in Denmark have to build more storage sites. Nobody wants that. So, the farmers, the farmers' unions, the ministry of agriculture, they are all trying to keep the norm figure low. But that is stupid. It should reflect the reality. It doesn't. And it is a political game of trying to keep this figure low because if we increase it to the reality, we all have to build more storage facilities, and that is going to cost money. And we don't want to do that."

But this "political" explanation is not enough: a low norm figure cannot account for the variation in acid consumption from farm to farm:

"We cannot explain why [consumption of acid varies from farm to farm]. We do not really know. It could be the food that [the animals] are eating (…). There can also be other things. There can be cleaning liquids they are using which may have very high pH or maybe the water has a very relatively high pH compared to other farms. Maybe also it is something in our process, because our process is not always the same: we have some slight variations in the way we set things up in different farms and maybe that has an influence on the acid consumption. We simply do not really know. That is why we are making the laboratory trial at the moment. We have just started to see how we can explain this variation in acid consumption."

This example shows that the controversies over the numbers in the technology list are not only about political manipulation. They stem from the uncertainty which surrounds the process of slurry acidification. Uncertainty relates to chemistry (the acidification reaction), to biology (a scientist whom we interviewed told us that one of the reasons for variation was, "beyond doubt", related to the animals' food diet), and to sociology as well (a farmer that we interviewed told us that he sometimes mixed rainwater with the slurry to make it more liquid, and observed that he used more acid in this case). In order to understand the source of variation in acid consumption, *CleanFarm* had to launch a research project, which combined laboratory investigations on the chemical and biological reactions underlying the process, and the observation and monitoring of a few farmers who used the *AntiAmmonia* system.

AntiAmmonia incurs costs, but it also enables the farmer to make savings. According to the table in figure 1, these savings become significant in the case of the largest farmers and may drive the total cost of the system down to 0%. Where do these savings come from? *CleanFarm*'s acidification technology adds sulfuric acid to the slurry; nitrogen is then better fixed within the slurry and evaporates less. But this process changes the composition of the slurry, which then contains more nitrogen and more sulfur. When it comes to spreading the slurry in the fields, farmers usually have to add nitrogen and sulfur; so, when the slurry is acidified, they need to add less nitrogen and sulfur, hence the savings. The value of these savings is calculated by multiplying the number of kilograms of fertilizer saved by the market price of the fertilizer. However, *CleanFarm* argues, this is not the only way to calculate the "income" of the *AntiAmmonia* system. According to a Danish legislation which attempts to reduce leaching, farmers can only fertilize their fields up to 15% below the "economic optimum". This limit is expressed in terms of quantity of slurry spread over the field, and here the law does not make any difference between "traditional" and "acidified" slurry: the calculations are based on standard numbers which convert animal units into kilograms of slurry and nitrogen. So the farmers who use the acidification system would be able to go beyond this limit – and "put as much nitrogen as the crops really need" - without infringing the law. This impacts the value of the "income" of the *AntiAmmonia* system:

"The extra nitrogen [contained in the acidified slurry] will then not just be replacement of fertilizer, but it would actually give more crops. [The farmers] will grow more crops. The value of crops is higher than the value of the fertilizer - that is why you put it on the field. So if we are allowed to calculate (…) the income expressed as the extra crop that you can produce, the value of the extra crop you can produce (…) is higher than if you say: 'But it is just the value of the replaced fertilizer'."

The changed composition of acidified slurry impacts not only calculative, but also farming practices. In the farm, slurry moves in between the pits in the stables, the storage tanks and the field; however, ammonia emissions from the field are subject to a different set of legislation which, as we saw in the example of nitrogen above, does not tell the difference between "traditional" and "acidified" slurry. This legislation prescribes, in particular, that in a number of cases slurry should be injected in the fields rather than simply spread over, in order to impede the evaporation of ammonia. However, the injection of acidified slurry does not have any positive environmental impact, because ammonia does not evaporate anyway. The environmental impact would rather be negative, *CleanFram* argues, because injection requires more machinery and more fuel, thereby generating additional greenhouse emissions. The company ran investigations to demonstrate that injection is not needed when slurry is acidified and had discussions with policy makers; it hoped that new legislation was on the way that would recognize the specificity of acidified slurry and would hence exempt farmers using *AntiAmmonia* from the obligation to inject slurry – an exemption that would represent a significant saving (estimated at up to 100.000 Danish krona in some cases) and would thus endow the acidification system with an "income" that could weigh against its costs. But for the moment this hoped for income was no more than a conjecture, and *AntiAmmonia* meant only costs to the customers to whom it was offered – a situation which made the whole sales and marketing process quite complicated:

"This is then the tricky part, because whatever happens, our system is costing money. There is not a case where you can say: 'Well, the farmer is actually gaining money from this.' You can see here. It costs them money."

What is the product worth?

CleanFarm's strategy for making the *AntiAmmonia* technology valuable relied on regulation. The entrepreneurs thus focused their efforts on transforming *matters of concern* into *matters of fact*. Regulation makes it a fact that farmers have to buy a system that reduces their ammonia emissions; scientific evidence makes it a fact that the acidification technology reduces ammonia emissions. It turned out, however, that a fact-making strategy raised serious problems. As we saw above, no sooner had facts been put forward that controversies started. The chemical, biological and social uncertainty inherent in the innovative slurry acidification process made both claims about the costs and the benefits of *AntiAmmonia* open to question, and farmers' associations proposed different numbers – which were themselves backed up with scientific evidence. A second problem related to regulation had to do with the value of *AntiAmmonia*: if farmers buy it only because they *must* do so, what is the product worth to them?

"[The farmer] doesn't care, he has to eliminate ammonia. He does not want to eliminate ammonia. He is simply forced to do. And the less it costs, the better. (…) This is very difficult, very difficult way of operating, because we are working with… yeah basically (…) we are working against our own customers. (…) Maybe there is a way we can show the farmer that this system is actually beneficial to environment. If we could show that it is beneficial… if we could show that it contributes to his bottom line, he won't mind so much investing in it. At the moment, the customer applying our system would much rather not buy. They are forced to buy. They feel forced to buy. (…) So we have a hard time explaining [the product's] value to the farmer, because the document [the technology list] clearly says that it is costing them money. (…) We cannot show that our system is actually beneficial to them. At least not in monetary terms, right?"

Faced with the problem of worth, *CleanFarm* attempted to demonstrate the qualities of *AntiAmmonia*. As we saw above, acidifying slurry allows saving on nitrogen and sulfur, and increasing crops' yield. Savings, however, are not straightforward to translate in monetary terms. As to increased yield,

"It is not tangible at all. Because you cannot measure it. You have to completely believe the surveys that have been done, the scientific documents which are there, because from year to year you always have a variation in the yield from the land. Depending on the temperature, the rain, the sun, you know… So a farmer cannot really say: 'Oh well, now I am getting 10% more yield because I have acid in my slurry', he doesn't really know. Most of our farmers say that they can see it on the crops; some farmers have both treated and non-treated slurry at their farms, and then they can take fields which are next to each other so they have similar conditions, and then they can see the difference. But it is not so tangible. (…) Because they are not selling the crop. They give it to their animals, right. To feed. So therefore, they don't see the… They see the cost. They have to buy (…) the sulfuric acid, they get the electricity bill, they get the maintenance bill (…). They do not get an invoice or a credit note saying 'Ok, I am getting this much money in the field'. (…) It is just that the costumer doesn't see the pay-offs so directly, but he sees the expenses, he doesn't see the income So…"

In other words, the valuation of the "yield increase" quality of *AntiAmmonia* is mediated by the scientific reports that aim at quantifying it; conversely, it cannot be visualized through direct observation. This quality is *evidenced* with theoretical arguments and empirical data, but it is not *made evident* to the farmers' eyes. Another quality put forward by *CleanFarm*, i.e. animal welfare, suffers from the reverse problem. It is a quality that appears relative to the other solutions to ammonia emissions reduction approved on the technology list, which, it turns out, harm animal welfare. One of these alternative solutions consists in changing the feeding of animals so that their excrements contain less nitrogen; however:

"If you lower the nitrogen too much, the animals get sick, they die. They start producing very little milk, so there is a tradeoff between reducing their intake of nitrogen and obtaining less nitrogen in the slurry. (…) Many farmers do not like this, because, they're growing the animals because of getting the maximum yield of its pigs: they have to grow fast, they have to have a low fat content; if it is dairy cows, the cow has to produce a lot of milk every day. And that does not work well together with: 'Ok, now I start restricting how much you can eat'. It is an intuitively counterproductive resource for farmers who simply do not like it. Because they feel it is bad for the animals, [he] feels that he is not treating the animals well."

The same problem occurs with other alternative solutions, such as lowering the temperature in the stable or limiting the openings in the slatted floors on which animals live. In one case, animals get chilly and some might die. In the other case, animals get dirtier. In both cases, there is a "tradeoff between animal welfare and environmental protection". Moreover, the conditions that make animals feel worse also deteriorate the "working climate": farmers and their employees are concerned with reducing the feeding of animals, the surrounding temperature and the cleanliness of the floors. By contrast to these alternative solutions, *AntiAmmonia* appears to be endowed with an "animal welfare" quality. This quality can also be translated in monetary terms, for sick animals produce less milk/meat and incur more veterinary bills; however, such a translation has not been stabilized yet:

"Then we have the animal welfare, which eventually also is money, right. (…) So if the animals are more sick they have more diseases, they will produce less milk, they will grow less pork, and [the farmer] has to give them medication more often. He needs the veterinary more often, right. But again, how much is this? We have no numbers. (…) But it is a very important parameter for our customers to choose our system, because they believe in the animal welfare and they believe that they actually get money back in terms of increased yield, because the animals are less sick, and less expenses to medicines and veterinarians, right. [But] there are no studies that show that. (…) Our original (…) investigations on ammonia emission showed that (…) the pigs in our group, compared to the control group, were growing faster. They had better food conversion and (…) lower mortality than the control group. But not statistically significant. So it could be just a coincidence, right. It could have been the other way around. We do not know. There are some theories that when you lower the pH in your slurry you decrease the bacteria activity, (…) so (…) maybe this reduced bacteria activity in the slurry leads to fewer infections in the animals, but it is theory…"

CleanFarm's quest for value has made emerge a number of qualities of the *AntiAmmonia* product. Some of them, namely ammonia emissions reduction and savings on nitrogen and sulfur, are taken into account by the technology list, and hence by farmers. Others remain outside of the valuation scope of this calculative device. Yield increase effects have been documented by various studies, but they remain somehow "intangible" to the product's users. Conversely, animal welfare and working conditions are noted and cared for by farmers, but there is no "quantification" of these qualities, no "monetary terms of expressing how much that is worth", which impedes their economic valuation.

Discussion and conclusions

The construction of clean-tech opportunities

Dominant theories locate entrepreneurship in the individual-opportunity nexus: alert individuals discover opportunities for profit (e.g., price discrepancies or unmet user needs) and attempt to exploit them by engaging in the development of new products and the creation of new organizations. Our case study challenges such views of entrepreneurship. First, the "nexus" that appears of relevance here is that of new technologies and public issues: an opportunity starts to emerge as concerns about the harmful emissions of agriculture are translated into the qualities of a slurry acidification technology. But is putting technologies and issues together enough to produce opportunities? It may be enough in a "creation theory" where opportunities are envisaged as the emanations of entrepreneurs' creative minds. What we observe in the case of *CleanFarm* is the gradual and effortful construction of a market space in which a technology that reduces ammonia emissions from slurry could become valuable.

We can describe this market space as a socio-technical network. Its construction involves establishing alliances with a wide range of actors. *CleanFarm*'s founders started by enrolling policy makers at the national and the European level in order to "build the issues" that their technologies attempted to address, and to ensure that the regulation "forcing" farmers to buy these technologies is passed on. The strict application of legislation also involves municipalities, which are in charge of delivering environmental permits, and NGOs, which monitor the process and can protest when the attribution of a permit does not appear to be justified. To make their decisions on whether a permit should be delivered or not, both municipalities and NGOs rely on the guidelines provided by the Ministry of the environment, which take the form of a "technology list". This list indicates, for each approved technology, its performance (in terms of ammonia emissions reduction) and its cost. Performance and cost calculations are based on the assessments of experts and consultants, and on scientific models and test measurements. This extends the opportunity construction network to two other types of actors: the scientists, who develop these models and measurements, and the professional organizations and technical institutes, who organize the testing campaigns. Professional organizations include farmers' associations whose mission is to represent the users that *CleanFarm* targets and to defend their interests. Users are also accompanied by environmental consultants, who advise them on the choice of technologies:

"We are fighting against 10.000 farmers within a big industry. Thousands of advisors: there are 500 environmental consultants, and then you have the pig consultants, then you have the cattle consultants, then you have the crop consultants, you have the financial consultants … There are thousands of consultants. So we are fighting a system of thousands of farmers and thousands of consultants, who are all trying to influence the industry in the other way. And we have an entire ministry: the agricultural ministry. The agricultural ministry, we do not talk to them directly, we talk to (…) the ministry of the environment. But they have of course also the influence by the agricultural ministry, right? And the agricultural ministry will be looking at the benefit of the farmer."

A crucial component in this network is the technology list. The numbers that it contains – and which, as we saw above, result from a complex chain of calculations, and trigger controversies - determine whether government makes the decision to implement regulation (are there technologies that allow environmental benefits at a "reasonable" cost?). It is on their basis that farmers and their advisors compare alternative technologies and decide which one to choose. The tables in the technology list fix the product qualities that will be taken into account by the user, and the value of these qualities (e.g., savings on nitrogen) as expressed in monetary terms. In this regard, the space in which a technology that reduces ammonia emissions becomes, or fails to become, valuable is that of the technology list whose function appears as similar to that of a shelf in a supermarket. To sum up, the process of opportunity construction does not only involve establishing alliances with actors such as ministries, NGOs, scientists, users and their representatives, but also building new market metrics and calculative devices which take into account the qualities of a "clean" technology and translate them in monetary terms – a step without which economic valuation cannot proceed.

Heterogeneity and materiality in valuation

The heterogeneity of the networks in which clean-tech opportunities come into existence reflects that of a valuation process assembling matters of concern, matters of fact, and matters of worth. *Matters of concern* are issues, such as farms' odor and ammonia emissions. Their formation coevolves with that of "concerned groups" (Callon and Rabeharisoa 2008), such as the neighbors and environmental NGOs who are affected by odor and ammonia emissions. The problematic situations – situations in which "there is something the matter" (Dewey 1939, p. 34) – made of issues and concerned groups trigger a process of inquiry that experiments associations between projected ends (e.g., the reduction of ammonia emissions) and the means to achieve them (e.g., the slurry acidification technology). Science plays a crucial part here, for it is able to mobilize a modeling and measuring apparatus that solidifies the characteristics of both ends and means and quantifies the causal linkages between them. The transformation of matters of concern into *matters of fact* involves government too, when scientific data becomes embedded in legislation and its associated regulation tools, such as the technology list. But neither issues nor facts are enough for clean-tech market opportunities to emerge. The entrepreneurs still have to turn slurry into a *matter of worth*, or as one of them put it, to establish the vision that slurry is "a value-stream, instead of a problem-stream". It is this third moment of valuation that failed in the case of *CleanFarm*. How can we explain that?

Several answers can be brought to this question. One could account for *CleanFarm*'s failure by resorting to a "political" explanation: the farmers' association had stronger support, compared with a 18-people start-up, and government attended to the interests of farmers in view of the electoral force that they represented for the forthcoming elections. As the entrepreneurs would sometimes put it, this is a "political game" and "they tricked us". An alternative answer, which we would like to suggest here, lies in the counter-productive effects of *compartmentalizing* and *abstracting* the process of valuation.

By compartmentalizing valuation, we mean dissociating matters of concern, fact and worth. Indeed, they can be conceived of as forming a linear sequence of stages in which specific actors and tools intervene: first, issues are brought forth by concerned groups; second, issues are turned into facts by science and government; third, facts become worth through a double step translation: customers *must* buy an ammonia emissions reducing technology and *AntiAmmonia is* an ammonia emissions technology. However, the case of *CleanFarm* shows that such a division of valuation labor can hardly hold. This is salient in the controversies that develop as soon as the value of the slurry acidification technology (its necessity, its environmental performance, its costs, and its benefits in terms of saving) is fixed into the tables of the technology list. Stricter regulation constitutes farmers as a concerned group – similar to the “orphan groups” (Callon and Rabeharisoa 2008) whose interests are excluded from market framings and lock-ins - which is brought together by issues such as the performance and cost of environmental technologies, and the future of Danish agriculture. The quantity of acid necessary to decrease the pH of slurry may well be proven in the laboratory, “but that is on the basic chemical principal; now [*CleanFarm* has] to make that work in real life”. Emissions are not easy to measure, would also farmers claim, and instruments are costly and need to be calibrated, so “if you go to the international articles (…), you will see a lot of numbers that are not correct”. Environmental protection has a cost, and imposing this cost on farmers decreases the competitiveness of Danish agriculture compared to other EU countries and thus threatens its future. One may see in such controversies no more than the skillful manipulation of numbers and the unwelcome intervention of political issues in normally straightforward calculations. But one could also see here a process of valuation in which both what we praise and what we price is at stake; in which multiple evaluative principles – corporate profits, environmental sustainability, the future of Danish agriculture – are put in play and might produce what Stark (2009, p. 6) calls a “resourceful dissonance”.

By abstracting valuation, we mean neglecting the materiality of the process through which goods are endowed with qualities. In the entrepreneurs’ business plans and Powerpoint presentations, the qualities of the *AntiAmmonia* system proliferate: compliance with regulation, ammonia emissions reduction, the ability to expand farms, savings on nitrogen and sulfur, dispensation to inject slurry in the field, extra crop yield, animal welfare, reduction of greenhouse gas emissions (namely, methane)… However, for these qualities to gain reality beyond the entrepreneurs’ discourse, they have to be made part of “valuation frames” such as the technology list. *CleanFarm* initially thought of this list as no more than a standard that their product would comply with, an “approved” stamp. Similar to the financial analysts’ reports discussed by Beunza and Garud (2007), the technology list is made of internally consistent categories, analogies and key metrics: the slurry acidification technology is an ammonia emissions reduction technology; it is hence comparable to other ammonia emissions reduction methods that rely on the feeding of animals or on the cleaning of air, for example; and it is hence assessed, like other environmental technologies, by the extra cost that it incurs for the farmer – a cost that may be reduced if the system’s “secondary effects” enabling savings on nitrogen and sulfur are taken into account. It should be emphasized that there is nothing straightforward in this translation; it corresponds to one possible configuration of the nominal, ordinal and numerical scales of valuation (Guyer 2004). For example, the design of floors in stables (with more or less large openings and hence more or less large surfaces through which ammonia can evaporate from the slurry pits beneath) is an ammonia emissions reduction method that appears as an alternative to *CleanFarm*’s product, but pertains to a very different configuration:

“Floor design (…), that is a different authority, because that has nothing to do with the environment, because that is something about basically agricultural business. It is regulated with some kind of standard figures for production: how much slurry does a cow produce and blablabla (…), and this floor design, you could expect that you will have this amount of ammonia in the slurry, and that means that you have this benefit into the field… but it is not on the technology list. (…) They have actually issued a new catalogue with a lot of new floor designs. They have not been tested technology- or environmentally-wise, but the Danish environmental ministry is just taking the figures from the agricultural ministry, and the figures they have made have not been for environmental purposes but have been more for standard figures to explain how much ammonia could get into the field.”

The example of floor design, which is handled as a "production" - instead of an "environmental" – technology, is telling in several respects. First, categorization is a crucial step in the process of valuation: a variation in the nominal scales of valuation entails variation in the ordinal and numerical scales; or, in other words, a different category is associated with different analogies and key metrics. Second, valuation is embedded not only in calculative devices, such as the technology list, but also in existing configurations of institutional divisions and user practices. Floors fall under the jurisdiction of the ministry of agriculture, while slurry acidification falls under the jurisdiction of the ministry of the environment. This has important consequences for the valuation of these ammonia emissions reducing technologies. Their environmental performance is measured through a translation supported by standard figures, in one case, and through experimentation, in the other. Their "benefit in the field" is taken into account, when the farm is modeled as a production site and is considered as a whole; conversely, it is left out of the valuation frame, when the farm is modeled as a pollution site and attention is focused to the most significant source of pollution, which is the stable. The realization of *AntiAmmonia*'s claimed values would thus require change in calculative devices (e.g., consider crop yield and animal welfare benefits in the tables of the technology list), in institutional arrangements (e.g., challenge the division of issues and competences between the ministry of the environment and the ministry of agriculture), and in farmer practices (e.g., identify and implement best practices to reduce the consumption of sulfuric acid, stop injecting slurry in the field). This point helps use understand the difficulties faced by *CleanFarm* in its endeavor to transform slurry into a matter of worth. It also sheds new light on the "political" nature of clean-tech markets – a point which we would like to underline in closing this paper.

What does it mean to say that clean-tech markets are political?

Throughout the discussions we have had as part of this case study, *CleanFarm*'s founders and managers have been emphasizing the "political" nature of clean-tech markets. Not only are these markets driven by regulation, which makes activities such as building relationships with policy makers, lobbying and "planting visions in central places" like parliaments, ministries and the EC a very important part of the entrepreneurs' work. Politics instills into the numbers themselves – even those from the tables of the technology list which are supposed to reflect the objective properties of different technologies, but actually hide a "political game behind", as our respondents have lamented.

In our view, the analysis of *CleanFarm*'s struggle to assemble environmental concerns and economic worth puts forward a different definition of the political nature of clean-tech markets. Let us turn back to the numbers in the technology list and the controversies that they trigger. It is tempting to reduce them to "political manipulation" and "paper exercises" detached from the reality of farmers' practices. But there is more at stake here. These controversies reflect the uncertainty surrounding the behavior of slurry and nitrogen, the measurement of emissions and costs, and the price that the collective is ready to pay to reduce emissions and protect the environment. While *CleanFarm* has tended to consider controversies pathological – a sign that politics is meddling into the business of science -, we view them as productive. In addition to producing knowledge of technical and social nature (e.g., knowledge about the behavior of nitrogen and about the behavior of farmers), these controversies put on trial lay theories of science and politics, urging the entrepreneurs to extend their enrolment efforts beyond the traditional institutions they first targeted, and to abandon the idea of cold facts that one could "put on her side" to achieve closure.

We would like to propose the following hypothesis: what we observe in the formation of clean-tech markets is not only an evolution of lay theories of science and politics, but a redefinition of science and politics themselves. On the one hand, the combination of regulatory tools, such as the technology list, and market mechanisms, relying on the comparison of the tangible qualities of goods, spur a search for quantifying emissions and demonstrating causal linkages, in which collaboration between scientists, firms and users plays an increasing part. On the other hand, while instituted configurations weigh on the process of valuation, enabling or impeding certain qualities to be taken into account in the calculation of goods' worth, the issues raised by such framings (e.g., the division of competences between the ministry of agriculture and the ministry of the environment) are likely to act on these instituted configurations in turn (Callon 2009). It is also in this sense that clean-tech markets are political: the valuation problems posed by their construction question the institutionally built-in separation between the matters of concern, matters of fact and matters of worth which clean-tech entrepreneurs attempt to assemble.

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