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Continuous discontinuation – The DDT Ban revisited

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Abstract

Although innovation is considered as creative destruction, policies oriented to the withdrawal of socio-technical assemblages, have not been specifically studied so far. The goal of this paper is to contribute to fill this gap and to provide some elements of analysis of these policies that we call ‘outnovation policies’ in sustainability transitions. As template, we use the case of the withdrawal of DDT, one of the major post World War II innovations, as an emblematic case of outnovation. So far, the literature on DDT represents DDT withdrawal as a major public decision that resulted from environmental damages related to its massive and pervasive use. DDT ban is represented as a victory of the environmental movements in a period of constitution of an environmental policy stream. The literature perfectly captures the process of problematization of DDT, once considered as a magic solution to eradicate crop pests and fight insect-borne diseases like malaria and which becomes an iconic poisonous product. Based on the analysis of its ban in three countries (USA, France and UK), this paper focused on the missing parts of the DDT ban narratives through the lens of the dynamics of the regime of regulation. The story of the DDT could then be re-written on very different grounds. The paper advocates that the DDT ban wasn’t a major turning point for the pesticide regulation. On the contrary and by many ways it has enhanced the legitimacy of the pesticide regulatory’ s actors to control pesticide hazards. On this basis, we discuss general questions related to outnovation, and point out the dialectic relations between external contestation and re-stabilisation of the incumbent regime. The key lesson for outnovation policy is that external contestation does not necessarily lead to a radically new regime. Rather, it may lead to major adaptations of the incumbent regime that are aimed at restabilization through integration of the critique and care of some of the externalities. Hence, outnovation policies should not be considered only as policies of radical change aiming at disruptive transitions, but also as finely tuned paradoxical processes of destabilization / restabilization of a given sociotechnical regime, which might be profoundly transformed in its composition and sustainable properties, but nevertheless still there.

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Introduction

Although innovation is classically considered as creative destruction process, policies oriented to the withdrawal of specific entities belonging to specific socio-technical assemblages, have been very little studied so far¹. The goal of this paper is to contribute to fill this gap and to provide some elements of analysis of these policies that we propose to call 'outnovation policies'. We define outnovation as a particular kind of process of detachment resulting in the de-association of a technology from a sociotechnical regime. Following Latour (2007), we will thus address outnovation policies as a political process aiming at the making and the regulation of new socio-technical assemblage performing and issuing this de-association.

This framework results from a comparative analysis of the case of the withdrawal of DDT in three western countries (the USA, the UK and France). DDT is one of the major post World War II innovations, and an already well documented as such and we intend to re-explore this emblematic case of outnovation. So far, the literature on DDT represents DDT withdrawal as a major public decision resulting from environmental struggles related to its massive and pervasive use. DDT ban is thus advocated as a 'victory' of the environmental movements in a period of constitution of an environmental policy stream in the US and the related creation of the Environmental Protection Agency. The literature perfectly captures the process of outnovation: once considered as a magic solution to eradicate crop pests (a "chemical crop insurance" trumpeted Scientist American, in June 1946²) and fight insect-borne diseases like malaria, it has also become an iconic poisonous product to be banned. The construction of DDT as a public problem results from a bundle of actions: the well-known fight of Rachel Carson, the structuring and mobilization of environmental movements, the construction of anecdotal evidence by professionals and amateurs, the production of scientific facts by scientists, etc. It took huge efforts to construct DDT as a 'cause', both a political issue for which one is ready to mobilize, and the chains of causes between DDT and actual or potential harms. However, existing narratives of DDT ban are partial as far as outnovation is concerned, since they do not consider the very process of de-association, which was involved and destabilizing the industrialisation of western agriculture, notably thanks to pesticides uses for crop protection. Indeed, the detachment from DDT occurs while intensive agricultural production had structurally become dependant on agro-chemicals, and synthesized pesticides. Yet, the DDT case may inform those mechanisms from a generic point of view, if analysed with two complementary approaches that enable to shed light on discontinuation in sociotechnical regime with an outnovation perspective:

- A processual approach, exploring how the many associations between DDT, farmers, the plants, the bugs, the malaria, etc. were unmade. The empirical question of this investigation is thus: how was it possible to untie links that were more and more thought and institutionally supported to be irreversible and a vital productive necessity?
- A retrospective approach of critical events and main incomes and outcomes of decision making, aiming at understanding the de-association processes in emerging environmental and human health regulation and in the crop protection regime. The empirical question corresponding to this investigation is thus: what can be learnt from a comparison of unlocking of the uses of DDT?

¹ This issue is at the heart of the DiscGo ORA Project (<http://discontinuation-governance.net/about-discgo/>), see Stegmaier et al., 2014.

² Howard C.E. Johnson, 1946, Chemical crop insurance, *American Scientist*, June, 258-260

In order to feed the analysis of outnovation policies, it is thus necessary to shed light on some unseen or underreported aspects of the DDT ban. Our focus on innovation and regulatory regime invites thus to examine two neglected aspects of this history: the endogenous dynamics of the innovation regime, and the comparison of the variations in outnovation national policies. Explaining possible variations invites us to address carefully the political aspects of outnovation processes, meaning: to avoid the temptation to naturalize detachment processes as being governed by scientific evidence delivery and technological progress on the one hand; and not to dismiss the importance of the environmental mobilization in the US as a performative symbolic worldwide narrative on the other hand. This symmetrical position about the DDT withdrawal enables to review the specificity of the US ban trajectory, since processes of withdrawal were slightly different in France and in the UK. We build upon this comparative account to show how outnovation policies may be part of restabilization processes and are thus not to be considered as drivers of a radical change: outnovation may both be incremental and a way to perform continuous discontinuation.

After developing our conceptual framework for the analysis of outnovation processes and the material and methods we build our analysis upon, we will analyse the narratives related to the DDT ban and present our main results concerning discontinuation patterns in the three countries studied. We then adopt a comparative approach of those three cases. Finally, we discuss our key findings in relation to socio-technical regime analysis and propose leads for further research on outnovation processes.

1. Outnovation as a de-association process: conceptual framework

Schumpeterian and STS approaches of innovation share a common representation of innovation as a process of emergent assemblages of technological artefacts, people and values. The etymology of the word innovation delivers an indication of this point view, as it frames the idea of renewing practices and uses by the adjunction or substitution of an object. The novelty of this object is not necessarily a condition of the irruption of novelty in a field of practices. According to such an etymological reflection, the purposive creation of novelty through the invention of objects that are dedicated to break into the reality of users appears to be a type of innovation that correspond to the Schumpeterian tradition of creative destruction of existing assemblage. The mundane industrial mind eye of innovation has retained, if not fetishized, this meaning, as the notion of breakthrough innovation is still carrying it.

In this “tradition”, it is rather intriguing that the abandonment of a technology, whilst it is considered as a side effect of the innovation process (the destructive part of the ‘creative destruction’), has not received much attention, as if the process of adoption would be sufficient to rationalization abandonment, insisting on resistance or even pointing the irrationality of non-users. Within this rather positivist vision of innovation much attention has shed light on purposive translation and strategies of successful breakthrough. Failure of innovation process has thus received less attention within STS work despite the axiomatic of strong symmetry (exception with some important case studies like the illuminating *Aramis* of Bruno Latour). Recently, within the framework of Actor-network-Theory (ANT), GOULET AND VINCK (2012) have proposed to frame a sociological enquiry of detachments in order to analyse in a systematic way the withdrawal of technological artefacts. However, they do not address the broader question of the relationship between the withdrawal of a technological artefact and the correlative changes of the socio-technical regime within which it is nested. Nor they pay attention to dedicated policy of detachment. Abandonment of a technology has thus rarely been put at the heart of a

dedicated policy until the late decades of environmental claims and the more recent claim for sustainability transitions that target the retreat of molecules, technology, practices and even large sociotechnical system like nuclear energy.

It follows that there is a growing need of academic studies going the reverse way, and to develop a stream of empirical investigation on policies that target the abandonment of a given technology, and to consider the process of this abandonment when it is driven by specific policies that orient to the withdrawal of specific socio-technical assemblages that used to be innovative (Stegmaier et al. 2014). In this general framework of discontinuation governance, our perspective on 'outnovation' benefits from earlier investigations about policy-making concerning the control of technological choice. From the first work about the emergence of Board of Technological Assessment (in the US with the OTA and in Europe with the Danish Board of Technology, see Vig and Paschen, 2000), a stream of work has described the framework, the momentum, the settings and the knowledge of technological assessment (TA), notably when TA has been exposed to controversy spaces which govern process of formal assessment (Cambrosio & Limoges, 1991). In the light of these investigations, an emphasis has been put on the structural effect of power-relations based on normative knowledge, but balanced by pluralistic mobilization in the appraisal of technology. This stream of reflection has issued concepts like Constructive Technology Assessment (Rip, et al., 1995), displaced the issue of impact measurement (Kuhlman, 1998) and considerably enriched the vision of public decision makers about uncertainty and precaution (ESTO report). Pluralistic views of technology are thus proposed has a key feature of policy making about technological choice (Stirling, 2008). The "precautionary principle" turn in Europe has thus convoked new approaches of governance for sustainable development (Voß et al., 2006) and various disciplinary inquiries about how system innovation - also named transition- can be influenced and governed by different type of actors (Elzen et al. 2004).

Looking at outnovation does not ignore this stream of works and their epistemological foundations that have grounded a knowledge capacity to unfold technocentric science and innovation policy. Paying attention to variety of actors, knowledge, artefacts and settings is maintained in our outnovation perspective, in order to embrace the socio-political processes about intentional technological retreat and to study long run processes of discontinuation that muddled through sociotechnical regime. It is especially the case regarding environmental issues, which are more and more associated with the claim of a political intentionality to break away from technologies presenting adverse effects on ecosystems and human health (STEGMAIER & KUHLMAN, 2014). Contemporary approaches of socio-technical transition policies thus need to take into account a quite understudied process: the one that leads to the eviction of a technology from the complex socio-technical assemblage it has been entailed in. Transitions are as much exploration of sustainable novelty than getting away of what has been considered innovative.

Different frames of analysis have been devoted to the study of technological change at the meso-level with the purpose to enlighten the understanding of innovation processes, such as technological trajectories (DOSI 1984), socio-technical systems and socio-technical regimes (see BORRAS & EDLER 2014 for a recent review). As compared to the two former approaches, ST-regimes focus much on socio-cultural dimensions rather than economic ones, and it is more embedded in sociological and institutional analysis. We shall thus favour this framework to position our discussions on outnovation. A ST-regime is defined as the *"rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems, all of them embedded in institutions and infrastructures"* (RIP & KEMP, 1998: 338; see also: BERKHOUT ET AL., 2004). This ST-regimes notion has enable robust analyses on transitions (GEELS 2002, GEELS AND SCHOT 2007, GRIN, ROTHMANS AND SCHOT 2010) and may be summarized as follows: transition is viewed as the phase between two states of stabilized

regimes and the dynamics of transition –represented as a multi-level process MLP- are constituted by the interactions between regime weakening, niches exploration and landscape pressure. In such a framework, the abandonment of technological artefacts is an evolutionary consequence of the process, and is not particularly analysed as such.

In the frame of MLP transition models, TURNHEIM AND GEELS (2013) have identified the necessity to focus on dynamics of destabilization of incumbent regime with the view to elaborate thick analysis of transition pathways. These authors have identified three main sources of destabilization: (i) outside pressures (related to the landscape or to alternatives in niches); (ii) performance problems (weakening of the technologies of the incumbent regime) and (iii) weakening of the commitment of industry actors. Considering this later source of destabilization, they identify gradual reactions of incumbent companies: (i) cost cutting; (ii) incremental innovation; (iii) more distant exploration; (iv) challenge of core beliefs. Hence, this contribution conducts to pay attention to the micro-dynamics of destabilization / restabilization. Following on this lead, this paper defines the process of outnovation as a dual dynamics between incremental changes related to the withdrawal of individual technological artefacts and changes of ST-regime. While focusing on product withdrawal outnovation is to be considered from three related lines of investigation: (i) restabilization of incumbent regime that has the ability to absorb external shocks; (ii) events that contribute to the unlocking of the incumbent association and open up possibilities of delayed changes of ST-regime; (iii) destabilization that affects the ST-regime and leads to global challenges while opening up alternative pathways. Hence, the withdrawal of products may be interpreted as a dialectical condition for the sustainability of the ST-regime when it allows both to focus on the critics and to promote incremental improvements. In such case, a regime of continuous incremental change is more likely to be observed than any profound changes. In other cases, the withdrawal of a product may contribute to changes within ST-regime, more or less directly. As it is the case for innovation studies, we could distinguish there between incremental and breakthrough outnovation. But we rather suggest that the key analytical aim is to explore the conditions that favour one or the other as well as the interactions between both, moreover the size and scope of the regime might also change through time. To address this analytical challenge that questions the notion of regime itself, it is necessary to analyse the technology withdrawal under three main analytical directions.

Regulation and innovation regime. Alongside, a global approach of the regime's dynamics is necessary, and a good proxy to explore the withdrawal is to look at regulation and innovation process. i) Regulatory regimes and the risks they aim at preventing and managing, (Hood et al., (1999) have pointed out the many ways to regulate risks); ii) innovation regimes, defined classically as stabilized formal and informal rules (routines) that are both cognitive and socio-technical (NELSON AND WINTER, 1977; DOSI, 1982).

The de-association process. As regards to its material properties, but also to its cultural and symbolic status, so as to understand the nature and strength of the relationships that link a particular technology to the regime. GOULET AND VINCK (2012) have proposed to explore the mechanisms of detachment involves (centrifugal association, reinforcement of existing relationships, association of new entities and invizibilisation of some of the existing associations).

The institutionalization of an outnovation policy. The dynamics of the regime may be described by an overlook on its key-elements, following the framework developed by Schot and Geels (SCHOT, 1998; GEELS, 2001; GEELS AND SCHOT, 2007), we shall take the opportunity to understand the dynamics of regime not only from its inside but also from its outside paying attention to the complex dynamics of social movements, knowledge production and circulation, and governance that originate the institutionalize of a withdrawal (MAGUIRE & HARDY, 2009).

2. Matter of facts, Materials and Methods

We build our argument on a specific case, which already received much scientific and public attention: the DDT ban. Both DDT itself and the banning process have been described as critical triggers in the dynamics of the plant protection socio-technical regime, in a way that we can consider DDT as a structuring emblematic technology: because it has been considered as a major innovation related to the Noble price of Paul Müller, and also because it has been considered as a major outnovation related to a “noble activist” in the name of Rachel Carson.

We focused on the DDT case, because it offers a quite striking contrast: it retrospectively seems to have played a significant role in these regime shifts, especially as regards to science, politics and culture; but the ways in which its withdrawal led to those shifts and the intensity of these changes are still partially documented. Maguire and Hardy (2009) provided an insight of this process as regards to the US situation: they described the DDT case as the “abandonment of widespread, taken-for-granted practices of DDT use” in the 60s’ and at the beginning of the 70s’ as resulting from a shift in problematization about pesticides used, driven by new actors and which undermined “institutional pillars supporting practices” (MAGUIRE & HARDY, 2009). Founding their approach on discourse analysis, they analysed the period of 1962-1972 as critical for the deinstitutionalization³ process. Their seminal work, though, called for more systematic comparison and left the issue of the socio-technical regime unaddressed, which is key to understand the significance of technology eviction.

Agrochemicals are a science-based industry, strongly dependant of chemistry, especially during their initial developing phase (DAVIS, 2014). It also involves plant biology and, in the case of insecticides, the (well and early in the US) structured field of economic entomology. In relation both to the economic and politic concerns about developing compounds with more and more targeted effects (and, thus, more and more possibilities of control devices), it is also concerned with ecology and ecotoxicology. Technologies involved thus tend to become more specialized, with a diversification of compounds and conditioning. Since the Second World War, three main families of compounds are produced and used for crop protection: organochlorines (or organic hydrocarbons), organophosphates, and neonicotinoides.

The market has been structured by a few global companies dedicated to pesticides production, with a high degree of concentration of the sector, and with a high R&D intensity (TAIT, 2001). At first largely supported by the fight against domestic pests, the market has then and until now been mainly driven by the high dependency of modern and mechanized agriculture to chemical pesticides. As regards to policies, if various sub-models of regulation characterize Europe and the US, both have known phases of pressure on the dominant regime, which may be described as the *controlled use* regime (DÉCOSSE, 2013). Political pressures on the regime appear to reach a new intensity with the Rio Conference in 1992 and the “blacklisting” of the “dirty dozen, and later on in Europe with the emergence of global reduction strategy for the reduction of pesticides⁴. These basic features show that the pesticides regime needs to be described with a dynamic approach and that the significance and impact of some evolutions remain un-assessed,

³ A process these authors define as “the process whereby previously institutionalized practices are abandoned”, mainly because they “have lost their original meaning” (MAGUIRE & HARDY, 2009: 150). This process supposes, according to institutional theory, “some form of purposive “disruptive institutional work ...to undermine these meanings.”

⁴ During the 2000’s the European Parliament and the Commission have shaped this strategy which has issued the so-called « pesticides package » in 2009: Regulation (CE) n°1107/2009 concerning the placing of plant protection products on the market, Directive 2009/128/CE establishing a common framework for the sustainable use of pesticides, Regulation (CE) n°1185/2009 concerning statistics on pesticides and Directive 2009/127/CE with regard to machinery for pesticide application.

because it presents both elements of meta-stability and successive socio-technical configurations leading to partial shifts.

We have thus carried out a longitudinal and comparative study on the DDT phasing-out process in the United States, the United Kingdom and France, noticing that the US-phasing-out process came first and seemed to impact what happened then after in the UK and in France. We thus focused on the 1942-1986 period, from the first uses of DDT to its official ban in the UK, which occurs later than in most of industrialized countries. We mainly focused on written primary sources, especially public governmental archives, and secondary sources, such as professional, advocacy groups and generalist press and literature. Each country has its own combination of relevant and available sources, which gives in itself a significant indication on the specific history and characteristics of national regulation regimes. This is also true for secondary sources. For instance, as the DDT case has been largely discussed in public arenas in the USA since the 1960s', both public archives, academic and advocacy literature are quite extensive. By contrast, in France, one can hardly find a reference to DDT in general medias or in parliamentary debates, which led us to use data-mining processes and to explore unreleased sources and under-exploited archive funds. We put our data in perspective with general characterization of the pesticides socio-technical outnovation policy. Thanks to these approaches, we could qualify finely these dynamics, assess the levers that triggered changes in the global regime, and propose a framework for the analysis of the de-association of DDT and related discontinuation within the pesticides regulatory regime.

Although this case is very well documented, we tried to re-examine the narratives the literature relies on, in order to understand the way "outnovations" emerge and are regulated. We will insist on two main points. First, we will show that taking into account national ways to withdraw a molecule like DDT proves efficient. We state that in France and UK, most of the DDT history has been carried out by endogenous - and not exogenously/mobilization driven - processes, in contrast with what has accrued in the US. Second, we will explore the structure and dynamics of the pesticides production and innovation regimes.

3. National DDT banning processes: patterns of discontinuation

3.1. The U.S. foundational experience of banning a miracle powder

Among the hundreds of chemical compounds synthesised since WWII to serve as pesticides, DDT is one of the most famous and controversial. Despite its withdrawal as an agricultural pesticide in most countries since the 70s' and 80s', and the dramatic decrease of its production and consumption, it remains an iconic product. Its story – how a miracle powder became a notorious villain - has been told and re-told, even in the most recent period⁵. Therefore it is not that easy to study the patterns of discontinuation through time, since a lot of discourses can be taken either as primary sources or as simply ex-post comments on previous events. This

⁵ In his latest book, *A rough ride to the future* (LOVELOCK, 2014), the world-famous biologist James Lovelock, who conceptualized the "Gaïa hypothesis", states that "Neither Rachel Carson, nor the green movement – nor the US government seemed aware of the direct human consequence of banning the manufacture of DDT and its lookalikes before substitutes were available ... In 1963 malaria was about to become effectively controlled. The insecticide ban led to a rise in malaria deaths to 2 million yearly, plus over 100 million disabled by the disease. » (P.127).

problem is largely reinforced by the fact that the DDT ban is still a matter of controversy today, and merchants of doubts have also to be taken into account in outnovation processes, of course.

Debates surrounding DDT use have not entirely vanished. They have been going on, since R. Carson's seminal denunciation of the dangers of pesticides in 1962 (CARSON, 1962 ; GRAHAM, 1970), a book until now considered as « one of the most influential (...) of the mid-20th century » (GROSHONG, 2002). Carson used DDT as a major example of the long-term deleterious effects of chlorinated hydrocarbons, which were at the time massively and indiscriminately used as insecticides. *Silent Spring* gave rise to a public debate in the United States: its publication in the New Yorker in June, 1962 was followed by what some opponents to Carson's thesis called a "noisy summer" (BROOKS, 1972; GROSHONG, 2002). The book was also denounced as irresponsibly advocating a complete ban of all pesticides, thus endangering human welfare and announcing the comeback of massive pests and to "desolate years".

Our extensive review of the academic literature shows that the discursive landscape on DDT can be synthesised in three key points. Should they come from pro or from anti-DDT, most narratives about the DDT ban: (1) emphasise the role of exogenous pressures, and especially stress the role of the emergent environmental movement in the 60s' and emblematic public figures - namely Rachel Carson - to trigger political change; (2) they also maintain that the claims and actions of those movements resulted in significant shifts in the regulation of pesticides and (3) implicitly suppose that the American history of DDT is paradigmatic, which materializes in the specific attention given to the 1962-1972 period. We propose to analyse these 3 elements to characterize both the type of problematization attached to the DDT ban (and more generally outnovation processes), the resulting blind spots regarding this process and the shifts it implied in the pesticides socio-technical regime.

As a matter of fact, the DDT case has several properties that allow it to be recycled until today as a debated issue. First, it was a non-targeted pesticide, widely used on a variety of insects and in very different contexts (fighting against human vectorial diseases and against agricultural and forest pests). It was thus well known in many countries, and both in industrial, agricultural, and domestic contexts (see Box 1.). Moreover, it was cheap, because DDT was not patented. Its rapid and worldwide expansion in the 40s' and 50s' made it a symbol of American post-war technological successes (KINKELA, 2011)⁶. This expansion was institutionally widely supported by the main private and institutional actors and endorsers of intensive agriculture, who built on the material and economic properties of the molecule and the variety of its packaging.

Box 1. Early uses of an all-purpose magical product

Early uses of DDT targeted many problems that appeared during WW2 with concentration of civilians and soldiers in camps, before its large use in Naples overload (See for instance: ROSE, 1944). The industrial capacity and the generalisation of the "hygienic use" of DDT started in Europe and in the US in 1942, before an expansion towards the protection of crops against insects (NASH, 2004), starting with field trials, for instance to eradicate greenhouse fly (HOLDAWAY, 1944). It is thus important to consider that the use of DDT for crop protection derived from hygienic uses and the fight against malaria in the first place, both part of the war effort, especially on the Pacific front (RUSSEL, 1999). The industrial capacities have thus been firstly defined and designed for this purpose, before it has quickly expanded just after the war for crop protection purposes.

⁶ See also, for instance, the testimony of B. Harvey, one of the top managers of the Agency for International Development, at the American Academy of Political and Social Science in 1966 : DDT is presented as one of the best examples of the contribution of American technology to development (ANNALS OF THE AMERICAN ACADEMY OF POLITICAL AND SOCIAL SCIENCE, 1966)

Second, the specific attention given to the 1962-1973 period is a clue of an almost exclusive focus on the banning process in the US. The period is marked by fierce debates involving top-managers of governmental agencies, agro-chemical firms executives and, increasingly, experts and scientists. They triggered several political statements at the highest level and institutional evolutions, favoured the reinforcement of the nascent environmental movement, and the development of new levers and tools that renewed the risk assessment methods related to the use of pesticides (DUNLAP, 1978). Hence, the dominant narrative enhances the role of science as a major factor of an increased political awareness towards the toxicity of chemical compounds used in agriculture, and DDT constituted an experimental case making possible better decisions - i.e. more rational because science based - to be taken and new regulation regimes to be set up. This shift was a major transformation, from a target of environmental struggles, DDT first but then other pesticide become matter of regulation sciences. So, as soon as in the 70s', the "DDT case" became a widely mentioned and studied case, at the same time idiosyncratic, unprecedented, and allegedly symptomatic of a new era for public problem setting through the use of political means available with the regulation of chemicals in the environment. Public concerns further manifested through the activities of various environmental organizations. Beginning in 1967, the Environmental Defence Fund, the National Audubon Society, the National Wildlife Federation, the Izaak Walton League and other environmental groups became increasingly active. They initiated court trials leading to the restriction of DDT use at both local and Federal levels in the US. The DDT case was important enough to be considered by Government Committees who issued four reports, in 1963, 1965, 1969 (DUNLAP, 1981; BOSSO, 1987; DAVIS, 2014, CH. 6 TO 8). All four reports recommended an orderly phasing out of the pesticide over a limited period of time. So, together with other conflicts and concerns, DDT was one of the issues that contributed to the construction of environment as a public problem and lead to the National Environmental Policy Act (NEPA) and the creation of the Environmental Protection Agency (EPA) in 1970 (see Box 2.).

Box 2. The new face of pesticides regulation in the USA after the "noisy years"

In the 70s', the pesticides registration activities of the USDA and the tolerance setting offices of the FDA were transferred to the new Environmental Protection Agency (EPA). The day after the EPA had been established, environmental groups began a series of lawsuits demanding that the Agency cancel DDT and a number of other persistent chlorinated hydrocarbons pesticides.

Congress completely rewrote FIFRA. The amendments had a far broader remit than the 1947 version of the legislation, covering for example, research policy, and controls over usage (BLODGETT 1974, P. 267). The new bill prohibited the registration of pesticides that cause "unreasonable adverse effects on the environment". Congress insisted that any risks be weighed against benefits, and consequently the term "unreasonable adverse effects" was defined as any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits to the use of any pesticide.

Under the amendments, all new pesticides had to be registered with the EPA, all existing products previously registered under FIFRA had to be re-registered under the new standards, and all registrations were automatically cancelled after five years unless the registrant requested a new assessment. The Agency also had the authority to "cancel" a registration at any time if new evidence demonstrated "unreasonable adverse effects". In addition, the amendments allowed third party interests to sue the EPA on cancellation or suspension matters (though not in the absence of Agency action), and supporting data (for example, on toxicity or efficacy) were made available to the public after the EPA had taken registration decisions about the product. Nonetheless, the Senate and House agricultural committees retained their jurisdiction over pesticide matters, and many of the proposals for stringent pesticide regulation died in those committees.

EPA further banned DDT in 1972. Thus, a withdrawal of DDT seems to entail a major technological, economical and political shift and to be driven by strong social mobilisation and political willpower

The dominant narrative stresses the crucial role of social mobilisation, of debates in public arena, and the strategic dimension of the ban. One can easily see it when noting the importance of a “pre-post” rhetoric in academic publications. As a matter of fact, the scientific literature accounts for a periodization of time that reflects particularly well the organization of discourses insisting on the societal dimension of this molecule. Three eras are generally identified by the literature: pre-DDT era (1934-1942)(O’HARA, 1946), DDT era (1946-1972), and post-DDT era (1973-1991; sensu BEDNARZ ET AL. 1990)”, cited in ALLEN, ET AL., 1996). This “pre-post” pattern covers a large range of scientific fields, from ornithology to history (JACKSON, 1976; JARMAN, 2012) and, later, social studies of science and regulation (WHORTON, 1976; DUNLAP, 1978; GAY, 2012; JAS, 2007) and ecotoxicology (HARDING, 1988).

Based on such a common account, the pattern of the DDT ban in the US has the following characteristics: (i) social mobilization is the main trigger, particularly when it relies on science-based data; (ii) this mobilization gains some importance since it is aligned with policy stream – the construction of the environmental policy; (iii) the pace of termination is short (10 years), the ban being total, and resulting from a coordinated decision process. More specifically, the common history of DDT ban stresses the role of a specific compound as a strong political breach (see for instance: TAIT, 2001). (iv) A particular importance is given to disruption and to the importance of discourse changes implying a shift in the way actors involved think, act, and take positions (MAGUIRE AND HARDY, 2009).

We argue that this point requires specific attention and research, for several reasons. The first one is that the US ban actually appears as a long and eventually reversible process. The use of the term “ban” hides a more complex reality made of progressive disengagement of incumbents from the promotion of the technology and from its use, while maintaining exemptions for specific agricultural uses. So phasing out process would be a more accurate term. The second one is that the phasing out process should be put in perspective with the effective use of the technology. Indeed, to assess the significance of the ban, one should be able to identify an inflexion point in the production and consumption of the compound. Thirdly, the very idea of an identifiable disruption should be examined since such a phenomenon is specific to the US case and not as obvious in France or UK, as we will see in the next section. The account of the US DDT ban is thus both informative and so specific that it gives only part of the global picture of the withdrawal of the DDT as a worldwide technology.

3.2. The French case: A discrete adjustment to changing international context

By contrast with the common account according to which the 60s’ are marked by a reinforcement of regulatory devices on chemicals, legislative framework remains very stable in France from 1943 until 1972. In 1943, under the Vichy’s State, a homologation system of chemical products is settled, with the explicit aim to improve efficiency of commercialized compounds and protect farmers from quality variation. The system relies on 2 expert committees, the first devoted to « antiparasitery products in agriculture » (CPAP), the second to the use of toxic products (ComTox). The ComTox is in charge of eco-toxicological effects assessments concerning cattle and humans. Each Committee examines homologation requests and delivers a report to governmental authorities, which takes the final decision.

DDT is homologated in 1947 as an insecticide, with special recommendations concerning precautions for use, especially concerning bees. The issue of insect resistance to DDT becomes visible in France through several crises during the 60s', directly challenging its efficiency and opening the way to the use of alternative compounds. Technical sources (professional journals, State services of control, etc.) report alerts as soon as 1946⁷. This leads the State services to recommend not using DDT alone but to use it in combination with other pesticides (lindane, toxaphene, aldrine) and/or alternate the compounds. Nevertheless the DDT is widely used during the 50's and the 60's, in crop fields and animal stables, and even recommended through the advisory system for crop protection (see a sample of a *Bulletin d'Alertes Agricoles* that advise the use of pesticides for various types of crops).

AVERTISSEMENTS AGRICOLES		BULLETIN TECHNIQUE DES STATIONS D'AVERTISSEMENTS AGRICOLES
PUBLICATION PÉRIODIQUE :		ABONNEMENT ANNUEL : 15 F
ÉDITION SPÉCIALE		
Produits pesticides homologués au 1^{er} Janvier 1965 utilisables contre les ennemis des cultures mentionnés ci-dessous.		
(Les doses sont exprimées, sauf indications contraires, en grammes de matière active par hl. d'eau).		
A. - ARBRES FRUITIERS		
1. — RAVAGEURS ANIMAUX		
Anthracnose du pommier :		Pucerons :
HCH : 100 g		Nicotine : 150 g
Lindane : 12 g		HCH émulsion : 200 g
DDT : 100 g		Lindane émulsion : 30 g
		Quastix amara (Puceron vert farineux du pêcheur)
Anthracnose du poirier :		Parathion méthyli : 30 g
DDT : 100 g		Parathion méthyli : 30 g
Lindane : 12 g		Melathion : 75 g
		Diazinon : 25 g
		Azinphos : 40 g
		Prothioate : 30 g
		Inchloréthion : 50 g
		Dithion : 100 g
		Fenitrothion : 75 g
		Isolan : 6 g
		Déméthion méthyli : 50 g
		Déméthion méthyli : 25 g
		Oxydemeton méthyli : 25 g
		Endosulfan : 30 g
		Phosphamidon : 30 g
		Diazinon : 30 g
		Mercaptos : 50 g
		Vandathion : 50 g
Carpospes des pommes et des poires :		Acariens :
Ascarate de plomb : 80 g d'arsenic		Parathion méthyli : 25 g
DDT (produit à 50% de matière active) : 125 g		Parathion méthyli : 30 g
DDT émulsion : 100 g		Diazinon : 25 g
DDT : 125 g		E.P.N. : 25 g
Méthoxychlorure : 125 g		Melathion : 75 g
Parathion méthyli : 25 g		Azinphos : 40 g
Parathion méthyli : 30 g		Phenakapton : 30 g
Chloroperthion : 20 g		Phenakapton : 30 g
E.P.N. : 25 g		Prothioate : 30 g
Melathion : 75 g		Déméthion méthyli : 50 g
Diazinon : 30 g		Déméthion méthyli : 25 g
Azinphos : 40 g		Oxydemeton méthyli : 25 g
Dithion : 100 g		Diazinon : 30 g
Fenitrothion : 50 g		Dichlorophosphazobenzthion : 50 g
Diazinon : 30 g		
Phosphamidon : 40 g		
Cutheryl : 75 g		
Tortueuse orientale du pêcheur :		
DDT (poudre mouillable à 50%) : 150 g		
DDT (émulsion) : 120 g		
Parathion : 25 g		
Chloroperthion : 20 g		
Azinphos : 40 g		
Mercaptos : 50 g		

The French translation of *Silent Spring*, published in 1963, was a success in France⁸. This sounds similar to the US case. However, it is not. The main difference is that, in France, the issue was globally contained and hardly overflowed experts and professional arena⁹. The authority of influential experts of the ComTox was instrumental to convince specific audiences that although Carson's claims were probably true for the USA, the French system was rigorous and protective of the population against dangers related to the use of insecticides. Also, experts of integrated pest management, although they might be natural allies, challenged the scientific accuracy of Carson's analysis when she called for a radical shift toward biological control (FOURCHE, 2004 : 139-145). They stated that the use of pesticides was necessary and that the main problem lied in the lack of competence of the government services in charge of controlling their good use; they also expressed deep concern about the spreading of approximate or false scientific statements in public opinion¹⁰.

⁷ The French Congress reports that pesticides induce resistance of dust mites that severely affect production capacity. DDT is the main target of these concerns. In the 50s', adverse effects of DDT are observed on bees. This causes severe problems when used on rapeseed in the flowering period. In 1950, resistance of grape worms to DDT is observed in Alsace. In the mid 60s', observation of resistance of Colorado beetle is observed, which triggers a reduction of the area of potatoes (FOURCHE, 2004). This problem is much discussed in professional arenas, and in State technical services.

⁸ "The reputation of the French publisher, Plon, the scientific status of the preface writer, the naturalist Roger Heim, Director of the National Museum of Natural History and President of the National Academy of Science[#], as well as the reproduction of large extracts from the book in the popular magazine Paris Match, made Rachel Carson's thesis on pesticides hugely accessible" (JAS, 2007: 369-370)

⁹ The Swedish case is quite different. According to EEA Report, just after the publication of *Silent Spring* in Sweden (1964), the Swedish government gave special funding to Stockholm University to set up a laboratory for the analysis of DDT in the environment (BERNES, 1998). These activities lead, *inter alia*, to the identification of polychlorinated biphenyls (PCB) as environmental contaminants in 1966. This research on environmental chemistry provided evidence that lead to the ban of DDT in 1970 (probably the earliest ban worldwide).

¹⁰ Even in the ranks of prominent naturalists, as the famous ornithologist Jean Dorst, author of the best-seller *Before nature dies*, the tendency was to alert against the uncontrolled use of pesticides, while denouncing the fact that, due to *Silent Spring* and its media impact, "many polemics and discussions dealt and still deal this tricky problem, very far beyond scientific and technic circles it should remain confined." (DORST, (1965) 2012: 243-244).

Yet, emerged in 1969 an international trade litigation with the USA about pesticides concentrations in dairy products: French dairy products were rejected from different countries, including the USA and the Federal Republic of Germany, that had settled a zero DDT residues in food products standard (FOURCHE, 2004). This led to the first restriction of the use of DDT: a ban of all organochlorines used for disinfection of animal stables. Pressure from FRG on Member States of the European Community for applying stronger rules probably acted as an important trigger. International arenas also played a significant role. This episode sped up governmental experts' attention to international expertise and recommendations on the use of DDT and got the phasing out process under way¹¹.

Finally, the DDT ban occurred as a 'normal' and silent decision that sounded the end of the cycle of a suspicious and not anymore useful product. For instance, the professional magazine *La Pomme de Terre Française*, dedicated to potato growing, didn't mention the ban, which is quite surprising because DDT was especially used to fight the potato beetle. That absence shows the ban didn't cause technical problems to farmers. The withdrawal process started in 1971 with a removal of certification as an insecticide for vineyards, fruits, potatoes and rape, following the recommendation of the CPAP. The CPAP stated that main uses had become "secondary" and that "more selective and less persistent insecticides" had replaced DDT. It pointed the position of WHO, that insisted on DDT being an essential element to fight against malaria and typhus, but also "recommend(ed) limiting its uses for other purposes". CPAP recommendation thus concluded that restrictions were necessary to "fulfil WHO's will and contribute to the decrease of DDT inputs in the world"¹². No toxicological argument was mentioned.

The clearance was nevertheless quite progressive in France. First, there were very few external pressures on the regime coming from social movements and very few informed actors criticising it. Second, the national legal framework didn't organise the withdrawal of once authorized chemical compounds. Consequently, the withdrawal process was composed of many micro and hardly visible decisions. A logic implication of this 'normal' decision is that, as it did not trigger any debate on the use of pesticides, it did not trigger any change in pesticides regulation¹³. The official discourse was that the French system was in advance on the US one, and that it was not necessary to reform it: so the ban of DDT was just 'business as usual' in a regime that presented itself as most efficient and able to deal with potential dangers (JAS, 2007). Finally, total clearance for agricultural and domestic uses occurred in 1976, as a result of the withdrawal of the last exemption (on corn borer moth), before the vote of the 1976 and 1978 European Directives, which settle a more stringent and compulsory regulation framework at the European level.

When analysing the DDT ban in France as a governance issue, one can thus hardly notice any discontinuation, but conversely a very soft transition, connected with international issues but absorbed by a very stable legal and institutional framework. Environmental and toxicological concerns remained secondary in the whole process and changes were not triggered by new knowledge: institutions involved did not address the issue directly – which does not mean that individual mainstream actors did not take them in consideration, but that the regulation regime itself was highly resilient to external pressure.

¹¹ French actors closely followed US debates on the ban of DDT. In 1969, French newspapers announced that R.Nixon has decided to ban DDT. Mass media misinterpreted the recommendation of the Environmental Quality Council (an advisory body located at the White House) that asked that DDT would be progressively phased out. This mistake reveals the attention of French actors for the decision process in the US and the stage of publicisation of the problem.

¹² CPAP recommendation, February 3rd and 18th, 1971.

¹³ Thus, one major methodological difficulty associated with the characteristics of the decision is that there are very few public sources on the French DDT ban as compared with the US one, which is characterized by a proliferation of sources and analyses.

3.3. The UK case: Institutional reluctance to market regulation and progressive alignment

The regulation of pesticides in the UK is marked by a strong institutional reluctance to market regulation (GILBERT, 1987; CONWAY, GILBERT & PRETTY, 1988). The *Pesticides Safety Precaution Scheme (PSPS)*, which lasted with very few adjustments from 1957 until 1984, was based on a voluntary agreement between industry and the Government: guidelines were the main regulation instrument, as opposed to mandatory procedures and controls¹⁴. As a result, the UK legislation concerning food residues or potential environmental damages stuck to very general principles, leaving economic operators with a very broad degree of freedom¹⁵. For instance, under the PSPS, manufacturers were not required to renew their product licence regularly and no real homologation procedure was settled. Moreover, very few possibilities of public control existed (WATTERSON, 1990). A specialized expert committee - the Advisory Committee on Pesticides (ACP)- was in charge of advising government departments concerning the safety of pesticides.

In the case of DDT, the interactions between UK and the US were, as soon as in the 50s', very strong: scientific research on adverse effects of DDT on bird populations was conducted simultaneously by British and American biologists, who developed strong collaboration leading to international symposia in the 60s' (SHEAIL, 1985; DUNLAP, 1978; DAVIS, 2014). Carson's book also raised fierce debates in the UK, but the debate had already been going on since several years when it was finally published: Parliamentary questions had been raised, special research groups on toxic chemicals and wildlife had settled within Nature Conservancy, a governmental agency founded in 1949. The ecological aspects of pesticides use were thus comparatively well assessed in the UK and DDT wasn't the main focus. The high-degree of structuring and strong commitment of environmental institutions into scientific expertise and Parliamentary debates at the beginning of the 60s' led to the inclusion of some representatives of Nature Conservancy in the Advisory Committee on Pesticides. But the following years revealed other dynamics within the interactions between the environmental movement and scientific communities involved in research on damaging effects of chlorinated hydrocarbons (SHEAIL, 1985): a consensus-building strategy prevailed, with the aim of developing progressive inclusion into governmental agencies and to reinforce the environmental movement's credibility with solid and long term scientific research and with moderate statements. This strategy led to an upholding of the pesticides issue on political agenda during a long period, but with a containment of radical criticism addressed to the regime. Meanwhile during the 70s', public concern shifted to other critical events and catastrophes (such as mining, black tides etc.).

The Advisory Committee on Pesticides issued two reports (1964, 1969) about chlorinated hydrocarbons. The first one pointed to the dangers of dieldrin on wildlife (continuing loss of adult raptors, widespread breeding-failure), and recommended to restrict its uses, being aware that this might trigger an increase of the use of DDT. Hence, the Committee recommends to reinforce studies of DDT and to conduct a further assessment 3 years later¹⁶. The publication of

¹⁴ In that context, occupational health, which led to the adoption of the Agriculture Poisonous Substances Act in 1952 constitutes a remarkable exception (CONWAY, GILBERT & PRETTY, 1988), even if its protective virtues remain discussed (WATTERSON, 1982).

¹⁵ Brickman et al. write in 1985 that "British regulatory standards for toxic substances are less consistent than those of the other three countries [the US, Germany and France]" (p.35) and that "the British carry flexibility to the extreme" (p. 53).

¹⁶ « They recognised that DDT residues in wildlife were more widespread than had been previously recognised, and they recommended that the use of DDT and HCH should be reviewed after a further period of 3 years. The Government followed these recommendations, and a ban on most uses of aldrin, dieldrin and heptachlor took effect in 1965. » (MELLANBY, 1992).

the second report had to be postponed to 1969, due to disagreements between the members of the committee¹⁷. Controversy focused firstly on hazard characterization for wildlife resulting from normal use of DDT, and on the other hand, on the existence of equally effective alternative molecules whose effects on the environment would be less deleterious. The Committee proposed additional restrictions, which effectively initiate the process of phasing out. In the 70s', use restrictions concerning DDT became more and more stringent. They first applied to food storage, household and barns, but also to some agricultural uses, for which alternative compounds were already commercialised. Some of the most sensitive uses have been suspended between two general revisions of the PSPS: it was the case for uses that imply immediate contact with humans and cattle. The clearance of DDT (i.e. the withdrawal of the last authorized uses) was publicised in 1984, with a governmental advertisement in the press. So in 1984, no agricultural use was allowed anymore.

Several political debates focusing on DDT occurred during the phasing out process, during which appeared a progressive disjunction between domestic issues and development issues, and between respect of business confidentiality and public access to environmental assessments. New regulation regime emerged at the end of this disjunction process, which allowed the problem to be re-framed as tractable. Yet, the DDT official ban was a consequence of the adoption of the Food and Environment Protection Act (1985). The 3rd part of the law established the principle of statutory controls on pesticides and defined a new pesticides regulation framework. The *Control of Pesticides Regulations (CoPR)* - 1986) implemented a marketing authorisation for new compounds, and also for the use of some existing products¹⁸. The implementation of the CoPR also marked the attempt of the British government to go over an emerging litigation with the European Commission before the end of the transposition delay for the European Directive of 1979.

In the UK, it is clear – as in the French case – that the availability of alternative compounds was considered by the main actors of the regime as a pre-requisite before engaging any phasing out process: so one can say that obsolescence governed the phasing out process. To summarize, the DDT ban in the UK is: (i) the end of a long phasing out process, resulting in the progressive extinction of derogatory uses; (ii) a consequence of the implementation of a new pesticides regulation regime, from which it is actually excluded; (iii) a consequence of the Europeanization of chemicals regulation.

The phasing out process is quite incremental within a flexible regulatory framework that define restriction of uses, knowing that most of the restrictions immediately follow ACP recommendations, with no original pattern for DDT, except that DDT is the pesticide that crosses the more numerous stages of evaluation from non danger to danger during the period (see: BRICKMAN ET AL., 1985; WATTERSON, 1990). At the end of the 80s', new legal framework strengthened risk assessment for chemical compounds, but - as organochlorines have already been widely excluded- very little additional knowledge was produced (WATTERSON, 1990). In the late 80s' and 90s', the DDT banning motives multiply, as environmental regulations set in European law tend to broaden the accountability of environmental and health adverse effects for risk regulation.

¹⁷ The main bone of contention was the recognition of adverse effects of DDT on wildlife, especially on birds. Nature Conservancy representatives in the ACP stuck to the explicit mention of adverse effects of DDT on wildlife, whereas opponents argued that scientific evidence was still lacking (SHEAIL, 1985).

¹⁸ So the CoPR implementation resulted in a series of sanctions for anyone advertising for products that have not been approved, selling them, providing them, storing them or using them. This set of offences became effective in October 1986.

4. Comparison of the three national cases

Our comparative purpose is to put at work the three main analytical directions that we have proposed to characterise and outnovation policy: the dynamic within the regulation regime and the innovation ST-regime of crop protection; the de-association process of the DDT as particular technology of this regime and the institutionalization of an outnovation policy, meaning the complex dynamics of social movements, knowledge production and circulation, and governance that originate the institutionalize of a withdrawal. Let's develop a crosscutting comparison of the three national cases studies according to these 3 directions.

4.1. Temporality of the phasing-out process

Comparative analysis of public control over chemicals has demonstrated that it is marked by lasting differences between countries (BRICKMAN ET AL., 1985; VOGEL, 1986; VOGEL, 2003). In our case, the dates of the DDT ban, the simplest indicator of the date of banning shows, are very different (Table 1).

Table 1. DDT ban in various countries (according to official sources)

<i>Date</i>	<i>Countries</i>
1970	Cuba, Sweden, Norway
1972	USA
1976	France, Poland
1984	Singapore, UK
1985	Canada, Chile, Romania
1986	Liechtenstein, Korea, Switzerland
2001	Stockholm Conference

This raises two questions: (i) what may explain such differences and (ii) what are the influences of the ban in a given country on the decision to ban in other countries, and mainly in respect of the US DDT ban? First, each of the three countries that we studied, had, at the time of the ban, settled a structured regulatory regime of chemicals. But, although globally pursuing the same goals, each of these regimes relied on well-marked characteristics and was embedded in strong and distinctive political traditions. Second, the official ban occurred at substantially different dates, which led us to the hypothesis that there could be a link between national regulatory regimes and the outnovation process. Third, the three countries shared some crucial characteristics, such as: well structured scientific communities with access to international scientific networks and international expertise, emerging environmental movements and institutions in the 70s', technology-based agricultural production, leading positions in international trade in the field of agriculture and agro-chemical industry.

In their comprehensive comparative study dedicated to the control of agro-chemicals, achieved at the end of the period we have decided to focus on, BRICKMAN ET AL. (1985) brought out several basic characteristics of regulation policies prevailing from the 60s' to the 80s'. They distinguish two patterns of regulation. Looking for an explanation of why what they identify as a largely distributed call for more public control leads to such distinctive regulatory strategies, they name 4 explanatory factors: the organization and process of national political institutions; the production and use of scientific information; the political strategies of private interest groups; the chemical control policies of international organizations (table 2).

Table 2 - The control of toxic chemicals: a comparative approach (drawn from BRICKMAN ET AL., 1985)

USA	<ul style="list-style-type: none"> - Complex procedures - Heavy reliance on formal analysis of costs and benefits - Openness of administration decision making - Active supervision of executive agencies by Congress and the courts
Europe	<ul style="list-style-type: none"> - Simpler administrative procedures - Greater informality in the analysis of evidence - Less complete public access to decision makers - Little oversight by parliaments or the courts

Their focus on control leads these authors to carefully examine the processes of introduction, assessment, and eviction of toxic compounds from national space. But as they do not consider incriminated chemical compounds as technologies, they do not take into account socio-technical assemblages and the outnovation process beyond its regulative dimension.

Yet, due to their strong association with modern, mechanized and productive agriculture, their massive use in open environments, their very positive symbolic association with food abundance and human health (such as in the DDT case), the regulation of chemical pesticides entails specific cognitive, social and political patterns that go far beyond the issue of toxicity for users. As a result, assessing the correspondence between regulation shifts and pesticides withdrawal gives an insight of the outnovation process if put in context with risk regulation regimes, problem framing and social mobilisations surrounding the withdrawal of DDT.

Post-war pesticides regulation was designed and implemented within national boundaries. Epistemic communities related to pesticides regulation were still weak and did not constitute a force toward harmonization. Nevertheless, pesticides regulation had some similarities. Similarities relied firstly on the main goals that were shared: regulation aimed firstly to guarantee the identity of products to be sold, to protect the users of pesticides against frauds, and to establish good conditions for market transactions. Second, the governmental oversight of pesticides regulation was located within agricultural departments who were also in charge of increasing technical efficiency and providing a favourable economic environment. In this context, standard for approving pesticides were mainly related to their efficiency; toxicological analysis was in its infancy and toxicological standards were still uneven. Regulatory systems were developed “in close interaction with multinational agrochemical companies” (TAIT, 2001). The emerging regulation regimes after the 60s’ actively participate to a “gradual replacement of one chemical group (of compounds) by another which often exhibited a different set of problems” (TAIT, 2001) and have thus been characterized as “reactive/preventive” (TAIT AND LEVIDOW, 1992; TAIT, 2001). In the sense they respond both by “cleaning” the market of incriminated compounds and by actively contributing to the structuration of methods for risk assessment. In the case of the United States, the regime became indeed, and in close relation to the progressive incrimination and eviction process of organochlorines, more stringent: “In no country was the banner of social regulation taken up with greater fanfare and promise” (BRICKMAN ET AL., 1985 : 20).

In the three countries, empirical evidence shows indeed both similarities and very different national temporalities for significant shifts and visible events in pesticides governance. Notably it shows that there is no systematic coincidence between major changes in the pesticides governance and the DDT ban: in the US, the DDT case appears as concomitant with a deep undermining of the regulatory regime. The legal framework is subject to instability, which

contrasts with the other countries: in the US, exemptions and decentralized regulations make non-linear change possible.

Table 3 – An overlook on the phasing out process

	USA	France	United Kingdom
Date of withdrawal	1972 (with exemptions)	1971 (with exemptions until 1976)	1984-86
Transparency / openness of the process	<ul style="list-style-type: none"> . Public announcement by highest political authorities . High degree of openness 	<ul style="list-style-type: none"> . No public announcement (silent decision) . Very low degree of openness 	<ul style="list-style-type: none"> . Public announcement without any visible political commitment (discreet decision) . Very low degree of openness to the public, openness to institutionalised ecological experts
Process	<ul style="list-style-type: none"> . New legal framework following the public announcement and preceding the effective ban. . Reversibility of the process, due to the characteristics of environmental regulations 	<ul style="list-style-type: none"> . Progressive restrictions closely correlated to international context evolutions but within stable legal framework . Irreversibility due to increasing European integration 	<ul style="list-style-type: none"> . Embedded in a new legislative framework, after a 20 years long restriction process . Irreversibility due to increasing European integration

In the UK and France, the DDT case appears to be less central in the evolution of pesticides regulation. In the UK, the phasing out process, from expert recommendations to total ban, is much longer (20 years) and not synchronised with the 2 other countries. The UK case shows that changes may both appear as a consequence of the phasing out process and as a cause. In France, the banning process is quick, at first glance synchronized with international events but with no apparent destabilisation of the regulatory regime. As shown earlier, DDT ban overlaps with important changes in the regulation regime in the US, but not in France, and in a very indirect way in the UK. Table 3 synthesizes key information on the phasing out process in the 3 countries.

4.2. De-alignment and detachment processes

We have just paid attention to the regulatory regime and the patterns of phasing out. We shall now compare the progressive detachment process in several arenas: professional space, science and expertise, social mobilization and the larger stream of environmental/health issues.

As regards to *professional spaces*, the UK and French cases make it very clear that the detachment process of main users (i.e. farmers) has already began when the phasing out process is initiated: extensive use of DDT very soon induced pest resistance, which reduced the efficiency of DDT. Indeed, professionals as soon as in the 40s' and 50s' observe resistance of pests to DDT. As there is no more public health issue at stake in Western Europe, DDT is moreover not directly protected by such an attachment.

As regards to *science and expertise*, we showed that although scientific data is marked by transnational dynamics of elaboration and diffusion, with the same cognitive material, expert committees do not come to similar conclusions concerning both the ability of the prevailing regulation regime to deal with toxicity and the appreciation of the relevant balance between

efficacy, safety and necessity of the compound, leading or not to withdrawal recommendations. We observe for instance three very distinct types of interactions between expert committees and international alerts and three versions of professional responsibility of the expert, when comparing for Comtox, ACP and Presidential commissions in the US.

As regards to *social mobilisations*, a remarkable alignment between the rise of the environmental movement, the publication of *Silent Spring* and the emergence of public concerns regarding the massive use of synthesized pesticides has been widely demonstrated in the US. The openness and adversarial nature of public debates and judicial arenas contributed to broaden the spectrum of actors concerned and involved. By contrast, two distinct patterns emerge from the analysis of the French and British cases. In France, the environmental movement emerges later. It is strongly linked to political radical criticism and marked by a very weak degree of institutionalisation before the 70s'. Besides, no alignment between scientific research, expertise and the environmental movement is observed, despite strong public commitment of influential scientists, mainly because the regulatory regime remains quite hermetic to the few-recorded alerts. Contrastingly, in the UK, the naturalist movement was well structured and connected both with the academic world and with governmental arenas. Not only did naturalists involve in field research, but also in political action and lean upon the US debates to put the organochlorines toxic effects on the agenda. But they did so by a strong involvement in the regulatory regime, instead of developing an outside criticism strategy.

As regards to *resonance between DDT and other environmental/health issues*, BRICKMAN ET AL. (1985) showed, the pesticides emergence on the highest political agenda at the beginning of the 60s' is strongly related in the US to public attention to carcinogenic effects and toxicity for human health (LUTTS, 1985). It is also related to the existence of structured environmental NGOs concerned with wildlife and the protection of the wilderness (DUNLAP, 1983). DDT spraying campaigns still occur on the US territory and US firms are involved in DDT production. This makes the detachment process both more likely to happen and more difficult, as resonance between DDT, health and environmental issues is strong (HAY, 2011): this resonance has both immediate effects, and long term effects by structuring adversarial settings and framing environmental issues. Potentially, resonance is also strong in the UK, as the protection of wildlife and especially birds is a strong topic, but investment in further research, less massive character of domestic eradication campaigns and the fact that other pesticides were simultaneously on trial led to a time gap, during which other environmental concerns emerged. Then, DDT has become largely obsolete. In France, concerns were mostly confined in professional spaces (problem of bees) and resonance was weak on the studied period.

As summarized in table 4, the de-alignment process finally occurs within various terms and conditions in each of the three countries we focused our analysis on. It also shows that in all of them, the de-alignment of DDT coalitions in professional spaces is strong: the detachment process is already engaged. In expert committees on the other hand, no real debate nor controversy seem to participate to the detachment process in France, while it is clearly the case in the US and the UK. The 2 last topics show a clear disjunction between the US and the two other countries.

Table 4. De-alignment of DDT coalitions in various spaces during the phasing out process

	De-alignment in Professional spaces	De-alignment in experts committees	De-alignment in public arenas (social mobilization)	Resonance between DDT and environmental issues
US	Strong	Strong	Strong	Strong
France	Strong	Weak	Weak	Weak
UK	Strong	Strong	Weak	Weak

4.3. Articulation between DDT problem framing and the institutionalization of an outnovation policy

When comparing the three phasing out processes, two distinct patterns come up. In the US case, DDT is a crisis triggering a public standing back and a strong disturbance of the crop protection regime. In the French and UK cases, the ban is the ultimate form of long term and quite understated evolutions, which concern the phasing out of chlorinated hydrocarbons with no original pathway for DDT. Table 5 thus shows that the DDT ban goes along with various dynamics of the regulatory regimes in the 3 observed countries, while the crop protection regime is also receiving new molecular innovation that fit to the incremental transformation of the regulation regime of chemicals placed in agriculture.

Table 5: Review of key elements of the regulatory regime – before and after the DDT ban

	USA		France		United Kingdom	
	Before	After	Before	After	Before	After
Compulsory registration	Yes	Yes	Yes	Yes	No	Yes
Degree of independence of the competent authority	Low	High	Low	Low	Low	Discussed
Standard of proof required/burden of proof	External actors	Producers	External actors	External actors	External actors	Discussed
Authorization for specific use	Yes	Yes	Yes	No	Yes	No
Control of conditions of use	Yes	Yes	Yes	Yes	No	Yes
Incentives for lowering the use of pesticides	No	No	No	No	No	No
Surveillance of health/environmental impacts of pesticides	Low	High	Low	Low	Low	Strengthen

One already noticed that the history of environmental regulations is closely linked to the DDT case in the U.S.: DDT ban is correlated both to a public event and to long-term evolutions, converging in such a way that substantial institutional shifts become possible. Problem framing during the critical period of the phasing out process concentrates on safety and efficacy and leaves necessity unaddressed despite the intensity of the debates (MAGUIRE & HARDY, 2009). The focus on the DDT more than organochlorines or synthesised pesticides in general tends to separate the compound from the more general problematic of the intensification of agrochemical uses. The fact that DDT was in the US a highly visible and symbolically invested compound paradoxically facilitated this detachment, because it had an autonomous public existence, as opposed to other massively used pesticides. Although governmental agencies, research teams and *Silent Spring* itself didn't focus on DDT, its salient role in US post-war politics went on when both organochlorines and organophosphates were denounced for their toxicity.

When DDT was banned, the will of actors who pushed for alternative pathways was to launch a vast process of re-examination of whole set of old products. However, this project was turned down and very few products were actually banned, even in the 70s' when the context was still in favour of phasing out dangerous products. The basic point was that, when important economic interests are involved, it is necessary to regulate the use of dangerous products and to provide all the guarantees to safeguard public health¹⁹.

Then, the neo-liberal turn of the late 70s' came with an anti-environmental policy that changed dramatically the context. But, when considering these changes with a long term perspective, timely and fast phasing out, following and accompanying a decline of the effective use of the pesticide and of its chemical parents, must be treated carefully. The US case is actually characterized both by a shift in the governance regime and by a continuation in the global pesticides production and use regime. In the long run, the US case gives DDT a symbolic status and triggers systemic changes in other countries and at an international level, more than it changes the domestic management of the product itself.

By contrast, the DDT case is neither central in France nor in the UK. In the UK, DDT is not the first chlorinated hydrocarbon to be banned and the phasing out recommendation of the ACP concerns all organochlorines. Expert committees seem more concerned by the effects of other organochlorines, which are used more frequently in the country. Even if R. Carson's book had a strong resonance in the UK, one can hardly notice a similar symbolic investment than in the US and what environmentalists kept of the book was not its focus on DDT but its general denunciation of pesticides. Despite what we could (very) schematically call its "peripheral status", there are nevertheless issues at stake: not so about the compound itself but about the conditions in which its ban and public debate about its ban challenges the regime: protection of the regime and prevention of institutional risk plays a role. The key-question is whether DDT participates in a protection of the regime or becomes a danger.

In France, the main problem that regulation device has to address is the interest of the agricultural sector. As soon as material evidence is given that there is no danger on the regime (confidence in the strength of the regime remains strong) and that substitution of DDT by other compounds is on his way, the detachment process is quick. In the UK, problem framing influences the detachment process in another way: the regime is periodically during the 60s' and 70s' challenged by criticism about its alignment on industry interests. So the very process of banning incriminated compounds endangers the regulatory regime itself.

It follows that the institutionalization of an outnovation policy relaying on the detachment from the technology is marked by very progressive steps and intermediary framings, even more the question of the necessity of pesticides remains salient during a long period of time. It might be analysed as a combination of the progressive incumbency of actors that carry a controversial civic epistemology as far as the crop protection regime is concerned; the pressure of insiders and outsiders within the regulation regime and the type problem framing that is mediating the public attention to the necessity of acting towards the withdrawal of DDT. We try to summarize the combination of those key futures of the process that has institutionalized an outnovation policy for the DDT (see Table 6).

Finally, there is neither evidences of convergence nor an alignment of the de-institutionalisation of DDT when observing the evolution of industrialised countries as regards to pesticides after *Silent Spring*. When broadening the scope of the analysis, even if some circulations and porosities may appear between countries, prominent actors such as governments, research scientists, experts and environmental movements reacted differently to the alert. Our observations thus show that technologies are embedded in strong national landscapes that

¹⁹ In France, such a trade-off constitutes the frame of the 1916 Law on Poisonous Substances.

evolve in relation with on the one hand, international dynamics of science, trade and the structuration of industries, and on the other hand, strong cultural contexts (civic epistemologies and the materiality of technologies).

Table 6 – Civic epistemologies and patterns of de-institutionalisation

	USA	France	United Kingdom
Civic epistemology	Contentious (resolved through conflict) Legitimization by mechanic objectivity	Neo-corporatist (resting on the confined and sectorial consensus building between professionals, experts and government) Legitimization by expert judgements	Communitarian (resting on shared perception) Legitimization by expert judgement and institutionalized debate
Insiders / outsiders pressures towards de-institutionalisation	Adversarial, open, public arenas / prominent role of outsiders	Entrenched, prominent role of insiders High influence of economic/professional interests on regulation (Experts within ministry of agriculture)	Entrenched, prominent role of insiders Discreet decisions / continuous process
Problem framing	- Growing importance of health (food residues - FDA) and environment issues - Dissociation between normal and exceptional situations - Dissociation between domestic use and exports	- Focus on national agriculture defence - Assertion of State prevalence, while acknowledging national interest in complying with transnational dynamics	- Focus on wildlife and need for long-term studies - Dissociation of domestic space and global space by economic and development arguments - Dissociation between agriculture and health issues

5. Discussion

5.1. Exploring the transnational dynamics within the detachment processes

The comparison of the three cases shows very different national pathways towards detachment of the technology, with, at least on the studied period, no critical movement towards alignment. Indeed, the detachment process is both the result of the weakening of incumbents' attachment to the technology and to what would be named in the MLP 'outsider pressures' or 'landscape pressures', the combination of the two being subject to strong variations. Our focus on national level must not lead thus to underestimate the key-role of transnational dynamics in the detachment process from the technology. Three types of transnational dynamics seem to have played a significant role.

First, as already mentioned, commercial trade of agricultural products and the pesticides residues issue was an important vector of coordination: it participated in the evolution of regulatory regimes towards the isolation of certain compounds and in the focus on health effects whether than ecological ones.

Second, the strong echo of the US debates on Western Europe induced both reactive attitudes from European government aiming at protecting regulatory regimes and the development of cost-benefits analysis, which led to get rid of compounds that could endanger them.

Third, in the same period (late 60's), DDT and organochlorines were put on the agenda of intergovernmental organizations like FAO and WHO. At the time some major countries were about to phase out DDT, these institutions worked on the possibilities to construct a double standard for DDT. Their position was in favour of a progressive phasing out of DDT for agricultural uses, but they argued for maintaining its use in the fight against malaria. Hence, they were applying a kind of empirical cost-benefit analysis that lead to consider that the costs of discontinuation of DDT in terms of human health were far too high (see Box 3.).

Box 3. - Dynamics of international arenas concerning DDT at the beginning of the 70s'

The 1969-1973 period was key to the construction of new frames for dealing with adverse effects of DDT and the advocacy for its ban.

In 1969-1970, FAO sets up a committee and organizes seminars and symposium and the issue of generalization of insects' resistance to DDT. They point out the risks of shortcomings for insect controls, due to the small number of insecticides families (only 5 families used), and launch an alert addressed to the international community.

In 1970, WHO and FAO reaffirm that the use of pesticides (including DDT) is necessary but recommend banning the use of DDT for specific use where alternatives are available (FAO, X) . In 1970, WHO issues an assessment report on DDT: it states that DDT does not have adverse effects on human health and that its use for fighting vectors transmitted diseases is highly beneficial. WHO sticks to the line adopted just after Carson's book: the absence of proof that DDT is carcinogenic²⁰. In 1972, the World Health Assembly, jointly organized by FAO, WHO and ILB points out the net benefits of the use of DDT and calls for "rational decisions".

Besides, the construction of the environment as a public issue is also reinforced by interactions in international arenas. In 1970, an International Conference is organized. It gathers Members of Parliaments, Pesticides companies, Farmers, NGOs, etc. One of the main recommendations of this Conference is to set up Ministries in charge of the environment in each State; another recommendation is to organize forms of coordination of environmental policies, etc. The United Nations Conference on Human Environment is organized in Stockholm in 1972; the first European Ministerial Conference on environment is organized in 1973.

Despite those dynamics, no duplication process was observed, but a series of circulations/translations between levels of governance, national epistemic, political and the constitution of a civic culture of questioning chemicals and toxicity. Indeed, if these institutional transformations and growing intergovernmental interactions on environmental issues were in favour of a growing harmonization of national policies, expert committees in the UK and in France did refer to international expertise to engage in the recommendation of a phasing out process for domestic agricultural use, even if still fierce debates take place between them and with many precautions. But if the DDT withdrawal was now on the agenda, first the reference to available alternatives left room to local interpretations of the relevant scope and rhythm of the phasing out process. And, second, it didn't trigger *per se* an inflexion of the regulation regime in these two countries: transnational interactions are resources used by actors who fight in the national space according to national rules.

5.2. Exploration outnovation as being both the de-association of a technology and a reinforcement of the socio-technical regime

The DDT has contributed to the early popularity of pesticides (particularly its persistence, low cost, very wide use), later it became the basis for public concern over possible hazards involved in the pesticide's use. Also, because of its iconic nature (remember that DDT was considered as a

²⁰ IARC followed on that issue the firm stance of the American National Medical Association as soon as 1964: NMA considered that no evidence that DDT may be carcinogenic had ever emerged from scientific research.

miracle pesticide, efficient on a large spectrum of pests and thus widely used beyond agriculture), DDT constituted the ideal target for opponents. However, their strategy was not to focus on DDT as such, but to use the case to fight more largely against all pesticides, therefore shifting from the singular to the global. If *Silent Spring* has transformed the discourse on DDT, this book was not a book on DDT but on the massive use of pesticides. Rachel Carson and others warned against the dangers of the chemical infrastructure sustaining the American post-war economic boom. She showed that chemistry had devastating consequences not only for her contemporaries, but also for future generations (KINKELA, 2011:110).

Almost concomitantly, arrangements built around the detachment of DDT became self-supporting in quite a short time. The shaping of the ST-Regime of crop protection went with the proliferation of molecules and of product conditioning, increasing the plasticity of the regime and its capacity to resist to the DTT destabilisation by a process of “incremental innovation through substitution and withdrawal”. It is to be noticed that at the time of the Rio Conference in 1992, DDT is one of the Dirty Dozens pesticides that are targeted by environmental stakeholders.

The DDT case is showing then that discontinuation in socio-technical regimes is marked by dialectical interactions between innovation, regulation and landscape pressures, which involve moves from a level of governance to another, but without automatically leading to another regime marked by the development of former innovation niches of innovation. On the contrary, our study shows that outnovation policies are institutionalising the withdrawal of a technology, namely here the DTT, but also contributing to the reinforcement of the socio-technical regime in the long term, thanks to the possibility to un-tie some elements and features that were once key to the regime. So then, resistance to discontinuation pressure may be achieved through the reinforcement of the credibility of the regime, by claiming its efficiency and responsibility within new standard of innovation and shifts in regulation that are triggered by the withdrawal itself. This is what we call “continuous discontinuation” performed by national outnovation policies, which have their own patterns and styles.

A key consequence of this point is that stabilisation of socio-technical regimes is also achieved by the management of change by the incumbents and by the outsiders. It also shows the plasticity of the ST-regime of crop protection: outsider driven destabilisation did not necessarily open windows of opportunity for niche-innovation in crop protection for instance, at least not during the period that we studied here.

5.3. Outnovation and meta-stability in the global regulatory regime

Taking the example of electricity, BERKHOUT ET AL. (2004) noticed that several possible levels for analysing socio-technical regime are available; as a result, what can be seen as a regime shift at the level of one input (primary fuel) may appear as a modest incremental change at the level of the wider regime (all productions, distribution and consumption of electricity). But, as GEELS AND SCHOT (2007) point out a distinction between the analytical framework and the empirical object is a prerequisite when thinking with a regime perspective. In our case, DDT withdrawal has been analysed as an outnovation process consisting in removing a technology from the crop protection regime. We have highlighted the complexity of the detachment process and the correlative shift and change in the regulation regime. We identified three major processes that have contributed directly to the meta-stability of the regime. These processes are constitutive of outnovation, in the way they contribute to the detachment of the technology from the wider regime.

The singularization process. The conclusion of *Silent Spring* introduces biological control (based on ecological knowledge) as an alternative to pesticides, but the outnovation process went the other way round. It extended the process of singularization of a “dirty one” to protect the whole.

The process of reduction/containment of the pesticides to the DDT was instrumental for making this problem governable. And, as shown above, thanks to the work of international organizations among others, the DDT issue is still divided in sub-problems. It remains acceptable for fighting against malaria, but becomes progressively unacceptable as an agricultural pesticide.

The “tunnel effect” of scientific research on DDT. From the early beginning of the DDT-era and until the 80s’, DDT toxicity has been considered as a matter of scientific enquiry. The production of scientific knowledge was fed by the need to gain enough evidence on hazards for taking ‘rational decisions’, but also on non-toxic effect to justify its use. Hence, in different countries, data collection and research concentrated on DDT, has not necessarily played a major role in the withdrawal of the DDT. Scientific production has been associated as much as delivering evidence of hazards to frame restrictions and risk assessment than associated to the emerge of a body of norms that define what is toxic or not and rule the authorization of new molecules and pesticides.

The substitution effect. Agrochemical companies that have quite early operated strategic substitution of the DDT have also governed the de-association of the DDT: it opened a substitution line of molecules, notably with synthetic pyrethroid. During the 60’s the market of molecules for crop protection clearly benefit from investments in R&D in full accordance with national food security policy and related objectives of yield maximisation in agriculture. At the pretty moment when DDT is at stake, the socio-technical regime of crop protection is blossoming, with knowledge production, molecule design, experimental proof making based on field trials, agricultural advisement, etc.

Conclusion

In the beginning of this article, we defined outnovation as a process of detachment resulting from the de-association of a technology in a socio-technical regime. Our approach was inspired by recent research analysing de-institutionalisation and detachment processes, and aimed at connecting them with regime-centred approaches. In our attempt to analyse outnovation process in the case of the withdrawal of DDT, we have thus acknowledged that several processes participate to the de-association of the technology but that they also seems to correspond to a capacity of the ST-regime to absorb destabilization. The outnovation process is then both outsider and insider-driven, and both types of actors being marked by intentionality or by unintentional side effects. Our findings suggest that the institutionalization of external contestation does not necessarily lead to a radically new regime. Rather, it may lead to major adaptations of the incumbent regime that are aimed at restabilization through integration of the critique. Hence, outnovation policies should not be considered only as policies of radical change. The DDT case illustrates that discontinuation in regime transitions (GEELS AND SCHOT, 2007) may be incremental or a way to perform what we have called “continuous discontinuation”.

Our study doesn’t reveal striking new facts, but it shows that new perspectives can be developed thanks to the analysis of outnovation processes through international comparisons. First, an outnovation perspective brings a thick comprehension of the dynamics of discontinuation in ST-regime, by analysing simultaneously narratives, innovation and regulatory regimes in various national situations. It enables to shed light and explain differences in temporalities, particularisms of “national style” in regulation regime and differences in the alignment/de-alignment of coalitions in various spaces during the phasing out process. Second, an outnovation perspective shows that a careful attention to the dynamic of adaptation of the incumbent actors may subsume the distinction between outsider/insider driven process of de-institutionalisation. We found variations among the three countries in the ways civic epistemologies and patterns of de-institutionalisation are combined. Thirdly an outnovation perspective considers concomitantly the de-association of a technology and the reinforcement of the socio-technical

regime. Finally it proposes to interpret discontinuation as being governed through outnovation policies that sustain the meta-stability of a regime.

Our key findings could thus challenge the use of the ST-regime evolutionary perspective, in two ways. First, it reinforces the need to explore the various types of transition pathways, as proposed by GEELS AND SHOT (2007). We show that the detachment of some important elements of the regime should not automatically be interpreted as a transition process from one regime to another, but may also consist in a self-reinforcement process, in which a cost/benefit risk analysis triggers the outnovation process without affecting the main components of the regime, nor its main incumbents. Technological discontinuation may reinforce the regime through regulated unloading, anticipation behaviours and postponed effects. Second, it pleads nevertheless for a careful attention to naturalizing effects when dealing with de-association processes, which are neither linear nor irreversible. As a matter of fact, there seems to be a symbolic discontinuation: DDT becomes the symbol of the rise and fall of chemical promises and thus focuses the attention of medias, attracts and structures controversies about pesticides, but this symbolic discontinuation, which may participate in the detachment process in the long term, is also a strong back-up for the regime and its champions, because it helps to demonstrate a capacity of self-purification and to advocate that incumbent actors are able to do the things better and safer.

Our analysis does not aim at being provocative against environmental struggle with the view to re-establish business success story. We rather suggest that major changes and shifts in sociotechnical regime need to be analysed with scrutiny and paying attention symmetrically to the various politics of transformation, being at the same time incumbent and external. We expect to contribute with this paper to an on-going discussion about the shifts in regime, bringing back a discussion about the politics of outnovation in sustainability transition.

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