Minerals and Magic Machines

A critical approach to modern agricultural technology and its connection to world-system flows of rare earth elements

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Human Ecology Division
Department of Human Geography
Faculty of Social Sciences

Author: Niklas Sjøbeck Jørgensen
Supervisor: Alf Hornborg
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Lund University

Postal address
Lund University
Box 117, SE-221 00
Lund, Sweden

Visiting address
Paradisgatan 2
Lund, Sweden

Telephone +46 46 222 00 00
Fax +46 (0)46 222 4720
Web https://www.lunduniversity.lu.se/

Title and Subtitle	Minerals and Magic Machines – A critical approach to modern agricultural technology and its connection to world-system flows of rare earth elements
Author	Niklas Sjøbeck Jørgensen
Department	Human Ecology Division, Department of Human Geography
Address	Lunds Universitet, Geocentrum I, Sölvegatan 10, 223 62 Lund
Telephone	046-222 86 90
Supervisor	Alf Hornborg
Examination	Master's thesis (two year) – HEKM51
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Abstract:

This thesis connects agricultural technology (ag-tech) within a Danish context to a world system of production in which rare earth elements (REs) play a crucial role. These elements are essential for modern technology. By applying the concept of machine fetishism this thesis investigates how ag-tech in Denmark is fetishized through political discourse. The concept of fetishism here signifies that the socio-environmental relations on which technology relies are mystified. These relations are then investigated. Denmark's ag-tech producers buy components and hardware from a global market with opaque supply chains. The amount of REs used is therefore uncertain, but due to their important role in modern technology and Denmark's push for more ag-tech, they are critically reviewed. RE-mining causes severe socio-environmental harm, especially in China, which produces 90% of the global supply. Using world-system theory, this thesis shows how China has established structures of unequal exchange. By doing so, China has risen to dominate the world system of rare earth and technology production. Due to China's dominance of REs and increasing global demand, new mining initiatives in Greenland, in the sea, and on the moon are being planned. It is concluded that the Danish belief in technology's potential reflects machine fetishism and that fetishism mystifies the environmental impact of technology elsewhere. It is therefore important that actions are taken to ensure sustainably produced technology *or* to decrease the demand of rare earths altogether. It is important since technology have consequences somewhere and for someone - if not in China, then perhaps in Greenland or in the sea.

Keywords: *Technology, ag-tech, agriculture, Denmark, rare earths, extractivism, mining, China, discourse, reductionism, politics, nature, machines, fetishism, world system, supply chain, critical realism*

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List of abbreviations/acronyms

CDA	Critical Discourse Analysis
DAFC	Danish Agriculture and Food Council
GDP	Gross Domestic Product
GNI	Gross National Income
GPS	Global Positioning System
RE/REs	Rare Earth/Rare Earths
WTO	World Trade Organization

I

Introduction

On stage at a recent farming technology conference,[1] addressing the audience is the chairman of the Danish Agriculture and Food Council (DAFC). While he describes his younger farming days, he recalls how he skeptically opposed change. Back then, he was against all the new methods and technology that he was told to try out. Grinningly he explains to the audience, consisting of major actors from the Danish agricultural scene, how he grew older and wiser. How he came to realize the potential of progress, of technology, and of change. He now thinks differently: "New technology? Yes! We have to try it!"[2] (Martin Merrild, chairman, DAFC) .[3]

Also on stage and agreeing with him, nodding their heads and smiling as he explains his transition, are two politicians involved in agriculture: the spokesperson for environmental politics from the left-wing party Enhedslisten, Maria Reumert Gjerding, and the minister of environment and food, Esben Lunde Larsen, who is aligned with the economically liberal Venstre, positioned slightly to the right of the political center. Their discussion of technology potentials is nearing the end and they laughingly conclude that it is rare, and almost strange, that they agree with each other completely on the beneficial potentials of agricultural technology (ag-tech). It leaves the impression that new ag-tech must have something significant to offer, since Venstre and Enhedslisten normally disagree on most things. The farmers present at the conference express some concern: what if I invest in this ag-tech and it does not work? The question keeps coming up doing the conference, and a range of representatives from tech companies, farmer groups, organizations, etc. present their positive view of technology. Almost all answer the question by referring to it as a process. As long as there is innovation and development technology will keep getting better. "The technology is right around the corner!" says a representative for AGROINTELLI, an ag-tech producer and innovator, referring to even more efficient and precise ag-tech than what is on the market now.[4] It is made clear that modern ag-tech is coming. Denmark is in the early years of integrating modern ag-tech into farming practice since much of it is still being developed or is being used on foreign

[1] 'Præcisionslandbrug: Kan teknologi erstatte miljøkrav?' on the 9th of February, which I will get back to.
[2] My translation.
[3] Field notes 09-02-2018.
[4] Field notes 09-02-2018.

soil. But where does the technology come from? It can seem that it is just a matter of being smart and innovative or getting the right idea. This does not explain where *machines* come from.

Some of the technology used in Danish agriculture is actually an innovative way of *putting together* physical and/or electronic components "from the entire world"[5] and combining it with software. As a study has shown (CompundChem 2014), an iPhone consists of at least 30 different elements from the periodic table. Included in these are rare earth elements (REs) which play a crucial part in making modern technology efficient, due to their potential in color screens, batteries, hard disks, sensors, cameras, etc. These elements are extracted through socio-environmentally damaging processes by especially China, which produces around 90% of the global RE supply (Klinger 2018, 2). Due to historical circumstances, China has risen to dominate the RE trade but is currently being challenged by new mining initiatives in, among other places, Greenland, Afghanistan and on the moon (Klinger 2017a, 3). The iPhone is an example of the complexity behind a piece of advanced everyday technology; it is assembled from a range of elements. It is well known that REs play a role in not just consumer electronics, but in most modern day technology (Massari and Ruberti 2013, 41-42; Filho 2016, 269). As stated by multiple companies involved in Danish agricultural technology, they do not know what their technology contains. They buy components from a supplier somewhere in the world, be it Denmark, Germany, USA, China, or South Africa. Their suppliers have bought components from other producers, who in turn have bought components from elsewhere. This chain can, in theory, be followed until a web of suppliers is revealed, its edges being the extractors of the minerals or elements used in components. The web is a mystified world system of technology production with long supply chains unknown to the end user.

When Denmark wants to invest increasingly in agricultural technology to create growth in a sustainable way, it is closely related to this world system of production. The connection between technology, a world system of production and the consequences of RE mining is what this thesis will investigate. It will argue that RE mining with its socio-environmental impact in especially China is a partly historical condition for reaching the environmentally friendly and economically flourishing future of the Danish agricultural sector, as imagined by politicians and organizations advocating for technology.

[5] From interview with Danish ag-tech company.

Aim of study

This thesis investigates how physical and digital machine technology plays a part in shaping the Danish agricultural sector by seemingly enabling simultaneous sustainability and economic growth, and how the capabilities of digital machines rely on a global system of extractivism.

In doing so, it engages with the following questions:

- How is the current political discourse on agricultural technology in Denmark constituted, and which ideas inform it?
- Can technology simultaneously enable sustainability and economic growth for Danish farms, as promised by various agricultural actors?
- Which consequences do digital machines have, for whom, and where?
- Which conditions are necessary for incorporating modern technology into Danish agriculture?

Conceptualization of technology

It is quite important to figure out how technology can be conceptualized and made tangible. Technology is a broad term, even when narrowed down to the agricultural kind. The modern concept positions technology as a cultural category with no universal characteristic (Hornborg 2013, 8-9). To Hornborg, technology is what is "technically feasible in a given time and space" (Hornborg 2013, 9). It is a very broad definition that serves to investigate technology as a concept. This thesis will take this conceptual definition as a point of departure but limits the area of technology to the kind that is used in agriculture, i.e. ag-tech. Hornborg is mostly engaged with energy-consuming machines[6] and has shown how they are part of a global system of exchange and are fetishized (Hornborg 1992; 2001; 2008; 2009; 2011). I will attempt to build on that literature by engaging with another kind of technology: *electronic* devices and machines that serve a digital purpose, i.e. electronic machines that provide digital data. Furthermore, it is necessary to stress that this thesis deals primarily with technologies that are *physical machines* and are part of modern ag-tech.[7] Therefore, it deals with only a part of the totality of technologies which includes e.g. know-how, organization, and methods (Liodakis 1999, 63). When needed, I will distinguish between the concepts of *digital machine* to refer to these machines, *digital technology* to include both digital machines and software,

[6] E.g. machines fueled by fossil energy and to some extent biofuels (Hornborg 2017).
[7] What Liodakis calls embodied technology, i.e. technology with a 'body'. This should not be confused with embodiment of labor and land that political ecology deals with (Liodakis 1999; Hornborg 2013).

and *ag-tech* as a wider term that includes all that is considered agricultural technology, including software, digital, and non-digital machines.

Specific to the case of Danish agriculture, digital machines are exemplified with sensors, drones, robots, computers, cameras, GPS-systems, etc. These machines often work together in various ways, making up a particular ag-tech, e.g. GPS-controlled tractors or a digital barn-environment control system. It is not the fossil-fueled tractor itself that is subject to investigation, but rather the modern digital machines that enable it to be controlled by GPS or to collect data through sensors or cameras.

Data and software

Data are a key issue in many of the new ag-techs, and it is exactly what many of these machines provide. They obtain data about soil, weather, geography, yield, pests, etc. which combined are sometimes labeled 'big data' (DTU 2015, 13-15). Data provide the opportunity to optimize production in a range of ways that can increase economic growth (DTU 2015). It is important to keep in mind that in order to analyze such data, software is needed. Software is not physical and not machine, but I will argue that software is dependent upon machines for both its creation and its use. In other words: you cannot have software without digital machines in the sense used here.[8] Many new Danish ag-tech companies produce software and apps for farmers to connect and analyze data, and ag-tech software is becoming a bigger industry which reinforces the industrial growth of ag-tech in general.[9] Software is part of the new technologies and though it is not physical, it is still intrinsically dependent on physical machines.

Purpose and contribution

This paper does not intend to prove that technology is bad. I believe that technological innovation has brought and will bring about benefits for society and environment, but that does not mean that we should be uncritical or oblivious to its consequences. Rather, I intend to elaborately show that technology has consequences. I do believe that a sustainability transition is urgent, and that green technology can play an important part in it, but I refuse to give in to the temptation of blindly trusting in human ingenuity and capacity for technologically fixing the problems that our planet faces and that have been largely created by certain parts of the world, e.g. by industrialization (Malm

[8] A theoretical discussion of what software is would be beyond the scope here. This paper takes the premise that software would not exist or have any use without digital machines.
[9] Field notes, 10-01-2018.

2016, 255-278). From a Human Ecology perspective, one can engage with technology as a phenomenon suspended between culture, power, and sustainability. Therefore, proving whether or not technology works on a practical level is not a relevant question. Rather, investigating what it means ecologically and socially when a technology enters the stage is more relevant. First of all, we should be critical of the faith in technology's capabilities. Secondly, we should be critical of the conditions of its capabilities. Thirdly, we should be critical of the production of technology. Fourthly, we should be critical of the political and economic agendas related to technological development.

"We need to understand that technology is not simply a relation between humans and their natural environment, but more fundamentally a way of organizing global human society" (Hornborg 2014, 123). By acknowledging technology as a cultural category and not simply an instrumental and clever rearranging of nature, we open up a discussion which to many is probably unwelcome, but which can be crucial to the environment and to people somewhere else.

Structure

This thesis has two main parts. The first analyses machine fetishism in relation to political discourse in a Danish context. The second analyses China's role in a world system of production in which REs extractivism plays an important role. The two quite different parts are connected in a peculiar way. Current Danish agriculture uses digital machines and will increasingly do so in the future. Many digital machines rely in turn on REs, which are mainly produced in China. It therefore suggests links between the drone used by a Danish farmer to secure growth and sustainability and socio-environmental harm caused by RE mining in northern China.

In the following second chapter, the thesis will take a look at current Danish agricultural politics in relation to technology and how it has been shaped by events of the past years. It will then present two examples of current technological initiatives relying on digital machines. This is done to provide a framework for the analyses that follow. Then I provide a discussion of the primary theories, concepts, and methodological approaches in order to discuss their applicability and to clarify them. This is followed by a discussion of the data produced and the methods for producing them. This includes reflections on limitations of both data and methods.

The third chapter engages with the Danish agricultural scene in order to understand how reductionist and instrumental perceptions of nature inform current perceptions of technology. An analysis of ag-tech discourse in the context of politics is then carried out. It shows that technology is perceived in a fetishistic way and that the current discourse reproduces this fetishism by advocating for haste, uncritical progress, and the enchanting potential of digital technology. The fetishism presented mystifies the social relation in which machines are embedded.

The fourth chapter investigates what REs are, the role they play in technology, and the socio-environmental impact associated with their extraction. The link between REs and Danish digital technology is established. This is discussed in relation to the supply chains of ag-tech companies which are made opaque by a complex world system of production. Therefore, the chapter analyzes China's rise to dominance in the production of REs and their current role in the world system of technology production. Finally, it looks into what the future of REs holds and discusses sustainability in relation to REs and suggestions for areas in which to take action from a Danish perspective.

The fifth and final chapter sums up the findings of the thesis and concludes that when Denmark wants to invest increasingly in agricultural technology to create growth in a sustainable way it is closely related to the world system of production and socio-environmental impacts elsewhere in the world. This close relation is mystified by machine fetishism, which pervades agricultural policies and technology discourse.

II

Framework

As I approached the venue of the recent conference "Precision Farming: Can technology replace environmental requirements?" a frosty Friday morning, February the 9th 2018, I was greeted by two giant tractors. Double-wheeled and looking extremely powerful, the tractors were deliberately parked in front of the old barn turned conference hall at Ledreborg Castle, which, besides hosting conferences, is a commercial farm.[10] The theme of the conference, as presented in the title, seems to ask implicitly: how big *is* the potential of ag-tech? Is it big enough that we can dismiss the requirements by which Danish agriculture must abide today? But, one could ask, why should we dismiss the environmental requirements to begin with? By going a couple of years back in time to look at the recent food and agriculture reform, we find part of the answer.

[10] Field notes, 09-02-2018.

The death-spiral of farming

The historical context out of which Danish agriculture has emerged and discourse is shaped, is important. It is a national history of greatness and pride, but lately also of crisis. In 1973 there were 80.000 full-time farms in Denmark, in 2002 there were 20.000. By 2016 that number had halved (Nielsen 2016a, 17-18). Agriculture contributes less than before to national GDP in many European nations, including Denmark (Borch 2007, 1046-1047). The trend has been called a 'death spiral' where massive debts, falling prices, risky monoculture farming, and growth imperatives have caused bankruptcy for thousands of farms, often with great consequences for entire families (Nielsen 2016a, 13-18). Public opinion of agriculture does not help farm economies either. In 2016 when asked in a national survey, 57% of the population said that environmental requirements should not be reduced in order to help agricultural economy.[11] This can be seen as an expression of public concern over the damage agriculture can cause the environment. It means that popular opinion will not grant it this kind of room for growth (Nielsen 2016a, 21). Danish Agriculture and Food Council (DAFC) and other agricultural institutions have been pushing farmers in precisely a growth direction by telling them that competition means everything and that in order to stay ahead, a farm needs to grow and optimize[12] (Nielsen 2016b). Competition exists both nationally and internationally (Landbrug & Fødevarer 2017, 1). On the global markets Denmark competes with other countries with less strict environmental requirements, which can partly explain the wish to change Danish requirements: it makes Denmark more competitive. This is significant considering that Danish agricultural exports[13] amount to around 25% of total Danish exports, or roughly 21,5 billion euros[14] (Landbrug & Fødevarer 2017, 11).

Growth, environment, and technology

Economic growth is presented as the ultimate solution in a long-term strategy published by the Danish government in 2015. With the title 'Growth and development in all of Denmark'[15], it shows different ways to increase growth in various sectors of industry and commerce (Erhvervs- og Vækstministeriet 2015). The strategy is a forerunner to a food and agriculture reform[16] published a

[11] E.g. by increasing the allowed rate of fertilizer.
[12] Fieldnotes, 09-02-2018.
[13] Including foodstuff, bio-based products (not for consumption) and machinery/ag-tech (Landbrug & Fødevarer 2017, 11).
[14] Around 160 billion DKK.
[15] Danish: 'Vækst og udvikling i hele Danmark'.
[16] Though the Danish name is 'landbrugspakke', i.e. agriculture package, it does reform some basic structures, hence I will call it reform.

few months later. On the 22nd of December 2015 this reform was issued by the government, backed by liberal and right-wing parties. The minister of environment and food at the time, Eva Kjer Hansen, said:

> Denmark has gained a Food and Agriculture reform[17] that lays the groundwork for renewed growth in the agriculture sector and that gives a green plus to the environment. With this agreement we say goodbye to old rules and introduce a modern regulation which has not been seen in Denmark earlier. [18]
>
> (MFVM 2016)

Benefits provided for both growth and environment is at the forefront of the agreement, as pointed out by the former minister. By changing the way that agriculture is regulated in terms of environmental issues, it should provide possibilities for growth. What this means in practice is that e.g. a single pig farmer is given the possibility of raising 40.000 pigs annually instead of 12.000 due to changing requirements on pig barns and the way they are monitored (NaturErhvervsstyrelsen 2016; Rosalia 2016). At the same time, these changed regulations aim to benefit the environment. The agreement acknowledges that nature and environment are globally under pressure, and that they provide the "foundation for growth and welfare" (MFVM 2016). This says something about why we need the environment in the first place. DAFC celebrated the reform and tried calming struggling farmers by stressing that it, along with an international economic upswing, would help farmers get on top again. But it has not yet changed the fact that Danish agriculture is 'death spiraling' downwards, due to massive debts and survival of the fittest as the underlying economic principle (Nielsen 2016a, 28-29). A question comes to mind while reading the reform and its promises: how is it done? What measures should be taken in order to secure growth, welfare, nature, and environment? According to the reform, the new system of regulations has to go hand-in-hand with new and better ways of farming. One of these new and better ways is incorporation of new *technology* into farming practices (Natur- og Landbrugskommissionen 2013, 89; MFVM 2016, 1-2, 18-20). Perhaps unsurprisingly, technology has long been the go-to when agricultural sectors are faced with crisis. Modern technology is generally thought to improve competitiveness, and thereby to help the agricultural economy grow (Liodakis 1997, 61-62).

[17] Danish: Fødevare- og landbrugspakke. Directly translates: Food and agriculture package.
[18] My translation.

An increased focus on developing the production of the future is also outlined in the reform. This means that certain measures are taken to increase innovation and research into agriculture, including an emphasis on technology and how it can provide the means for simultaneously creating growth and benefiting the environment (MFVM 2016, 19). It can therefore be concluded that many of these innovation initiatives were strengthened by the reform, both because of the new regulation system which created opportunities to think big in terms of investing in new agricultural technology and because of increased funding and awareness of these initiatives (MFVM 2016, 18-20). Lowering requirements is potentially bad for nature and environment, but good for growth. Danish agriculture needs to be good for both. Therefore, technology is perceived as part of the solution, as stated in the reform and government strategy, since it can create sustainable growth by simultaneously increasing production and lessening environmental impact. The next section will take a brief look at some of the actual ag-techs using digital technology that are relevant for the future of Danish agriculture. This is done in order to show how the technology dealt with here is partly already in use and partly still being developed. This hybrid existence is important for understanding how ag-tech is fetishized. Machine fetishism relies partly on the *future potential* of technology.

Precision and moon pigs

The Ministry of Environment and Food and DAFC launched a partnership in late 2017 with the aim of leading Danish agriculture down a path of more data and technology. The partnership underlines that precision farming is regarded as a central part of the future of agriculture (MFVM 2018). Precision farming is all about collecting and analyzing data in order to optimize production. It encompasses a wide range of GPS-systems, robots, sensors, computers, machines, and software. What is specific to precision farming is that a farmer obtains digital data, which can be almost everything ranging from drone photos of fields to the number of certain bacteria in cow intestines. It can be data from fields, animals, soil, plants, etc. A farmer can thus save time in the field, be notified if there is pest attacks or disease and spread fertilizer according to plant needs in certain areas by juxtaposing plant data with GPS-controlled tractors and fertilizer machinery. Drones can fly in and drop beneficial insects to counter a pest attack when discovered. Drones and satellites provide images of the fields. Sensors detect soil-, water- and air composition, wild life, and insects. The possibilities seem endless, and there are many ag-tech companies offering different solutions. More wood is thrown on the tech innovation fire through the partnership of the ministry and DAFC. They state that current technology must get even better, and new innovative technology must be developed[19] (Ravn 2017; Jakobsen 2018; MFVM 2018; Poulsen and Skov-Jensen 2017; Bjørn-Hansen 2016; DTU 2015; FutureCropping n.d.; Mikkelsen 2017).

Another project specifically mentioned in the reform is the private-state collaborative 'Moon Pig Project'[20]. It is a large-scale pig facility brimming with new technology which will enable a single farmer to annually produce 40.000 pigs, or even more, compared to the 12.000 currently allowed. It can be done due to the interplay of the new regulation and requirement system implemented with the agricultural reform and various digital machines that measure and control environmental impact and animal welfare. The project was launched already in 2012 and demonstration facilities were planned for the past years, but due to complications with the owner of the land on which one of the facilities was to be built the project was put on hold in 2017 (Sand 2017; Lorenzen 2016; Rosalia 2016; NaturErhversstyrelsen 2016).

Theory and methods

In this section I will introduce some of the theory and methods applied in this study. In the first analysis, the concepts of machine fetishism and discourse will help explain the role of technology in Danish politics. The second analysis deals with rare earth extraction and its connection to technology. Analytical distinctions provided by world system theory and critical realism help to explain how complex mechanisms in a historical world system of production connects with technology used in Danish. Finally, I provide a discussion of the data used throughout the thesis and ethical principles with regard to gathering it. Although it is not until chapter IV that it will be used analytically, critical realism is my fundamental scientific stance and will therefore be dealt with first.

Critical Realist stance

While some philosophers busy themselves competing over who can ontologically claim reality by writing the most intricate piece of text possible, other people take ontological and epistemological standpoints and work from there in order to actually say something about the character of reality. I subscribe to the latter and will therefore briefly describe the stance I take in order to ground the study.

[19] Field notes, 10-01-2018 and 09-02-2018.
[20] Danish: Projekt Månegrisen.

I will take a critical realist stance in this thesis, meaning that there is a reality independent of human consciousness and that there exist certain causal powers in social structures. I distinguish between intransitive (referring to static objects of reality) and transitive (dealing with fluctuating objects of reality) dimensions of knowledge. The world of which we speak (intransitive objects) will not change when our discourses or theories about it change (transitive objects) (Sayer 2000, 10-11). By taking this stance I position myself between positivism and constructivism. For this thesis, acknowledging the transitive and intransitive dimensions means acknowledging that there is a physical reality to machines which is independent of how machines are socially constructed. At the same time, it acknowledges that social constructions of machines can affect reality and vice versa.

Distinguishing between the real, actual, and empirical is also a useful approach. The real is what exists, whether natural or social, and its structure and power (e.g. banks and their ability to create money). The actual is what happens when the structures and powers of the real are activated (e.g. a bank creates the amount of money needed for a loan). The empirical is what can be experienced and/or observed (e.g. buying a house with a bank loan) which can relate directly to the real or actual, though some structures and powers cannot be directly experienced or observed, e.g. dormant, inactive structural powers (Sayer 2000, 11-12). Distinguishing objects of knowledge this way creates a foundation for dealing with them categorically and for looking for causation and conditions for phenomena of the world, e.g. the increased use of digital technology in Danish agriculture.

Causality is important to critical realism since it deals with causal powers, or mechanisms, of real structures, the conditions for their activation and the outcome of their activation. By investigating causality of events and phenomena, one can gain a greater understanding of the powers at work, be they observable or not. I find interesting the process of moving from phenomena to mechanisms and structures by *retroduction* (tracing the causality and conditions of empirical objects back to generative, real structures) in order to discuss their relation in an abstract and critical way. Moreover, abstraction can provide a foundation for further discussion of e.g. agricultural policy, which serves the emancipatory purpose which critical realism aims at (Yeung 1997, 59-61; Sayer 2000, 16). The aim here is not to undertake a thorough critical realist study, but rather to use its important tools and concepts to gain a specific understanding of the complex structure that the world system is. RE extraction is a part of such structures and governed by their mechanisms. Critical realist tools will help us understand how Chinese rare earths end up in machines somewhere in the Danish countryside.

Machine fetishism

Alf Hornborg's theory of machine fetishism is relevant for analyzing the role of ag-tech in Denmark. Hornborg claims that fetishism applies to all modern machines, but he investigates mostly energy-intensive machines (Hornborg 2014, 121; Hornborg 2013; Hornborg 1992). This thesis will attempt to expand the theory into the realm of digital machines which do not necessarily require a high energy input. They are also *dependent* on energy resources, if not for operation, then for their production, and Hornborg's argument on unequal exchange (Hornborg 2013, 25-6) is therefore relevant here as well. But, instead of 'testing' the theory on Danish ag-tech, it seems more interesting, and within the scope of this thesis, to see if and how fetishism goes beyond the unequal exchange of energy sources, i.e. fossil fuels (Hornborg 2013, 19-20; Hornborg 2014, 119-123), more specifically how it mystifies the materiality and material sources of the machine *itself*.

Hornborg uses Marx's notion of fetishism to extend Marx's insight that capitalism obscures social relations between people by representing them as things, e.g. commodities and money. Machine technology is in the same manner represented as exogenous to society and intrinsically and autonomously productive (Liodakis 1999, 68; Hornborg 2013, 10, 27-28). Fetishism is different from animism in that it *represents* relations between people as relations between things, while animism is the *experience* of relations to things as relations to people. In relation to technology, one could say that relations between people, e.g. the machine's production chain, is represented as a relation between the machine and crops. In being exogenous to social relations, technology is seen as a 'cornucopia' (Hornborg 2013, 10) with autonomous agency, that, if put to use, efficiently increases production. I will argue that this also relies on the idea that nature has the inherent ability to produce more with the same or less input, i.e. getting more out of less. Countering this way of regarding the capabilities of technology is the idea of a zero-sum world, in which environmental loads are displaced to other parts of the world, e.g. production of fossil fuels for machines. The concept of unequal exchange challenges the notion of a cornucopia, which will be elaborated upon in the section on world system theory.

That technology is socially exogenous also makes it exempt from political critique, while in reality, technology is endogenous to social relations and should be approached as such (Liodakis 1999, 70-71; Hornborg 2014, 128). Because technology is categorized as objects it becomes exempt from critique, since objects are viewed as intrinsically neutral and natural (Hornborg 2013, 36-37). On the contrary, if one looks closer it becomes clear that "(…) 'technology' is a cultural category"

(Hornborg 2013., 9), it is not politically neutral, and neither are machines just objects with intrinsic natural attributes. Technology is embedded in social and political relations, has environmental consequences, and is used as a way of organizing global society. Machine fetishism mystifies and obscures these relations and makes technology appear politically neutral, magical, and a gift to humankind as a whole (Hornborg 2013; Hornborg 2014; Hornborg 1992; Liodakis 1999, 68-76).

Discourse

This study will not undertake a thorough discourse analysis since it is not within the scope of the paper. Instead, it will engage with some characteristics of political discourse, which Fairclough and Fairclough (2012) have described, and apply analytical tools from critical discourse analysis (Janks 1997). This will help contextualize political, ag-tech discourse in Denmark and thereby unravel some of the principles governing it. By doing so, it creates the possibility of exploring discourse through the lens of machine fetishism, and vice versa.

Political discourse consists of narratives, stories, strategies, and practical arguments. In relation to crisis, e.g. the agricultural 'death spiral', it is part of determining its outcome by ideologically interpreting it. How the crisis itself and the responses, e.g. technology, are explained, narrated, interpreted, and represented is what make up the political discourse. It is attached to the actors engaged, such as institutions or persons, and the context in a wide sense. The reproduction and contestation of power in political discourse is important (Fairclough and Fairclough 2012, 1-7, 17-18). Though political discourse analysis also engages with the character of argumentation and deliberation, this paper will rather focus on the relation between political discourse, perception of nature, and machine fetishism.

Language and text are social practices and are the means by which historically contingent social relations are reproduced or contested. What is important is to identify these interests and relations by unraveling what lies behind the text (Janks 1997, 329). In other words: critical discourse analysis provides the means to read between the lines. It bridges discourse with materiality in the way that it engages with how discourse is operationalized and materialized, e.g. suggesting investments in technological innovation that materializes in actual applicable technology (Fairclough and Fairclough 2012, 83-85). By distinguishing between explanation (social structures), interpretation (processing), and description (textual object) – which is reminiscent of critical realism's real, actual and empirical - it opens op the possibility to unravel some of the underlying principles out of which a discourse arises, how it is enacted and reproduced, and what social and material consequences it might have (Janks 1997, 329-330). This approach is useful in exploring discourse on ag-tech, which is a very politicized field with politically and economically powerful actors. Many discourses of technology exist, but the one under investigation here is specifically about ag-tech and is political in character.

World system theory

According to Wallerstein (1974), the capitalist world economic system can be divided into different areas which, through their interrelations, make up the world system. These areas are core-states and peripheral and semi-peripheral areas. The core-states are characterized by a strong state and an integrated culture and ideology. The peripheral areas are characterized by a weak state or the absence of one. Despite a tendency to deal with *states* in world systems, Wallerstein stresses that we should rather deal with *areas*. There is a disparity between political areas, i.e. states, and geographical areas, e.g. mountain ranges, which will be relevant to the case of China and rare earth mining. The semi-peripheral areas are in between core-states and peripheral areas and tend to act as both. They are both exploited and exploiters. They also serve the function of suppressing peripheral pressure on the core-states since they consider themselves better off than peripheral areas and would therefore tend to support core countries if peripheral revolts would occur. The semi-periphery is crucial for maintaining the trimodal world system. Areas and states can over time shift between these positions as the economic world system changes. At the root of this organization of the world is *unequal exchange*. For Wallerstein, unequal exchange is a net transfer of surplus labor value towards core countries.

Contesting labor theory of value, Hornborg defines unequal exchange as the saving of time (labor) and space (land) with e.g. yield-increasing technology at the expense of a loss of time and space elsewhere in the world, e.g. for the production of technology and its required energy input (Hornborg 2013, 14-5, 40, 83-101; Hornborg 2014, 130). Machine fetishism obscures the connection between the machine itself and the environmental and social loads it creates elsewhere, i.e. the social and environmental relations in which it is embedded, and make it seem as though its capabilities are a matter of a relation between machine and nature. In Marxian theories of unequal exchange, there is a systematic flow of surplus from the periphery areas (and to some extend the semi-periphery) to the technological advanced and industrialized core-states. This surplus is understood by most Marxists as value but can also be seen as an ecological surplus: for instance, energy. Hornborg (2013) shows how peripheral time (labor) and space (land) are appropriated by core-states in the forms of raw materials and other products. Unequal exchange is necessary for the expansion of the world market to sustain the world system (Wallerstein 1974, 229-233; Grell-Brisk 2017, 2-9; Hornborg 2013, 18-20).

Some have argued that the trimodal world system (core, periphery, semi-periphery) has since the 90s gradually changed into a quadri-modal structure, where the periphery is divided into lower and upper periphery. The complexity has become greater in the system and there are more people living in semi-peripheral areas than in the periphery. A large periphery was Wallerstein's original premise for a trimodal system (Karatasli 2017; Grell-Brisk 2017). These changes in the world system and China's position in it will be relevant in understanding the role of rare earth minerals, digital machines, and Danish political struggles for growth, although China might seem very far away from the yellow rapeseed fields of Denmark.

Choice of theory

Technology is hybrid. It is both material and conceptual. Machine fetishism bridges the transitive and intransitive dimension in the sense that it relies on both discourse and socially constructed perceptions of technology, on the one hand, and a material reality, on the other. Critical realism distinguishes between these phenomena and provides an approach that considers both dimensions important. The concept of discourse is important to the transitive dimension of technology as it can provide concrete examples of how machines are fetishized through our language, i.e. are socially constructed as technology. World system theory is a *model* of the world that can help explain the structural conditions for the existence of the machines we see today, and how they are mystified. It can help explain why reality is constructed in various ways, but in taking a critical realist stance the *reality* behind these constructions are not neglected.

Data and methods

The data upon which this thesis builds its argument stem primarily from desktop research, but includes data from fieldwork, email correspondences, and short telephone interviews. A substantial amount of research into both webpages and news articles, and also some into printed materials such as brochures, has been carried out in order to gain insight into policies, political ambitions, and the historical context of Danish agriculture. At times, the research carried out has been reminiscent of investigative journalism, i.e. looking for connections between technology in Denmark and REs in China. This has included looking into the details of political papers, legislative documents, technical specifications of technology, company supply chains, etc. This research has been based on the journalist's questions: who, what, why, where, and when (Storey 2009, 25-26). By attempting to answer these questions it was possible to constantly determine if a given element, e.g. a company or a report, had relevance and, if so, to what degree. Asking the journalist's questions helped me to gather knowledge about the most important actors, the minerals and technology in question, the political and economic incentives, the locations of RE production, and about how the past has shaped the present.

Fieldwork

Minor fieldwork was conducted twice. I attended a meeting called AgTech Day[21] in the headquarters of DAFC, to which I could gain access due to having carried out a four-month internship with them, ending only two months in advance. It was a meeting set up for Danish ag-tech companies and DAFC to meet and discuss future collaborations. The other fieldwork was conducted at a conference called 'Precision Farming: Can technology replace environmental requirements?',[22] which included actors from a range of companies, organizations, and research institutes, as well as farmers. Participants included the Ministry of Environment and Food and DAFC. During the events I adopted the role as 'minimally participant observer' (Bryman 2012, 443), since I was taking notes about what was said during the conferences but also participated by small-talking and doing a short presentation of myself, as did everyone else. They were one-day events and therefore not continuous ethnographic fieldwork, which would have required many more meetings with the same type of actors (Bryman 2012, 432). Participating in the events still gave me valuable insights into dominant discourse and relations between the actors and was a way of snowballing contacts for me to pursue later on.

Emails and interviews

I sent out emails to 15 companies involved in Danish ag-tech and three RE-magnet producers, see appendix 1. Most of the companies attended either the ag-tech meeting or the precision farming conference. I mentioned in my email that we had met before, and thus established some rapport and hopefully willingness to respond. One company did not want to participate, and two companies have not responded. Initially a few gave very brief and unclear answers and did not reply when

[21] Danish: AgTech Dag.
[22] Danish: Præcisionslandbrug: Kan teknologi erstatte miljøkrav?

I asked for clarification. I took this as unwillingness to participate. A few were a little hesitant but agreed to participate when I contacted them on the phone. Out of 18, I have managed to get answers from 15. Of these, ten short, open-ended telephone interviews were conducted and five answered questions by email.

Limitations

The methods and data are limited in the sense that more thorough investigation into the *quantitative* use of REs in Danish digital machines could have established the extent of the connection, i.e. the amount of REs used in Denmark. The opacity of supply chains and the world system of production has made this difficult. Also, I could have expanded the research into the suppliers of components both in Denmark and outside, in order to trace the supply chain downwards, but it would require more time and could prove to be difficult. Another way that could have provided insights is tracing a specific digital machine used by a Danish ag-tech company. This would probably require a collaboration with a willing ag-tech company. Expanding the research and investigating the complexity of global supply chains could strengthen the argument further and provide insight into the world system of production in general. Another thing that might have limited the responses from the ag-tech companies and organizations I reached out to by email or phone is that I did not properly make sure to tell them that they participated anonymously, since I never intended to mention any company names, so as to not harm them in any way.[23] This might have caused some of them to be hesitant and to limit the information they were willing to share (Bryman 2012, 136-137). Despite this, I mostly experienced willingness, which could be due to my undisclosed research questions, as explained below.

Ethical considerations

I have taken a situationally dependent and slightly transgressive ethical stance, meaning that when I attended the meeting and the conference and when I wrote ag-tech companies asking for information that I could potentially turn against them, I deliberately did not tell the entire truth (Bryman 2012, 133). Neither did I lie. Had I disclosed my actual purpose, i.e. linking Danish ag-tech to REs and showing that technology has negative socio-environmental consequences elsewhere, none might have replied, since I would be critiquing their very business. Instead I chose to do a polite

[23] An exception is when I participated in the conference on precision farming, since they here speak to an audience including media. The ones speaking at the conference are larger companies while some of the ones I have contacted are small start-ups that I do not wish to see publicly exposed.

inquiry in which I disclosed that I was interested in agricultural technology and its future in general. See appendix 1 for the emails sent out. I did not want to ask directly about REs at first, but when I did not get a reply I sent out an email asking whether they had seen the first, asking an additional question about REs, thinking that it might probe them to answer by being a little more aggressive. When going against a politically determined initiative, this approach positions the research politically. I do finally take side in the political debate when challenging mainstream discourse and calling for a critical review of policies. However, I consider the study independent of political parties, actors and organizations. It is worth noting is that there is no funding behind this thesis, which is often the case for research into industry and commerce (Bryman 2012, 150-151).

Being 'alone' against the industry, politicians, and organizations presented here has limited the research in some ways. Besides being restricted by a time frame, I could have been more aggressive when approaching ag-tech companies. I could have engaged even more in research akin to investigative journalism in unraveling the underlying world system of production. But I had a hard time finding the leverage needed to be able to put pressure on these actors. I chose instead to address them politely and as a student needing help in his research. On top of this, I have built some of the argument on already existing investigative journalism, e.g. Zetland (2017) and BBC (2015).

III

Ideas, politics and machines

Historical ideas in discourse

Let us go some centuries back in time, more precisely to the 16th century. Back then, new ideas about being and knowledge emerged. Philosophies, including Cartesian dualism and the Baconian perception of science and nature, contributed to the shaping of nature as female, unknowing and irrational, and the mind as male, knowing and rational. Through the rational mind, matter, and thus nature, became knowable and rationally tangible. Western thought and science in the 16th century adopted these ideas. Along these lines Francis Bacon shifted the focus from knowing nature, to *controlling* it,[24] which changed the scientific agenda of the time. Increasingly, nature was seen as mechanistic instead of organic, and *mastery* of nature's mechanic systems became the aim of science

[24] Though he would call nature 'her' due to the gendered perception of nature in relation to the scientific mind (Lyons 2000, 32-34).

(Lyons 2000, 32-35). Some argue that the instrumental use of nature was further enforced historically by Christian ideas that puts man morally above nature, justifying the exploitation of natural resources and animals (Soper 1995, 22-23). A separation of nature and culture became integrated in Western thought, ontologically and epistemologically, but the dichotomy is not universal for humanity as a whole. It is specifically Western and should be seen as such (Ingold 2000).

The emergence of dualism, the nature-culture dichotomy, and scientific mastery of nature gave rise to a certain way of engaging with nature and doing agriculture. The cyclical and biological aspects of nature and farming started to be seen as limitations to agricultural science in the 16th century. Science began looking for ways to overcome these barriers, to appropriate and optimize the mechanical workings of nature. This led to a normalization of an agricultural science that focuses on technology such as chemicals and machine innovations that increase productivity by actively modifying the mechanics by which nature is perceived to operate (Lyons and Lawrence 1999, 29). Leaping back into the present, I argue that when Western agricultural science today aims to optimize yields and production by applying human ingenuity as lubricant to nature's cogs and wheels, it echoes the Western dualism that emerged in the 16th century. Mind shall be master over matter; science shall master nature. The official statement from the 2015 reform states that the reform is:

> (…) a paradigmatic shift for environmental regulations of the agricultural sector, in order to better brace the food and environmental sector for *increasing* the raw material base and exports as well as help in creating growth and employment in all of Denmark – in *cooperation* with nature and the environment. [25]
>
> (MFVM 2016, my italics)

From this can be read that agriculture should be optimized for the sake of humans. Dualism is reproduced so that the prosperity of Danish citizens is one domain, while the mechanics of agriculture and nature is another. We have spent centuries dealing with nature and agriculture from within this dualist epistemological mode-of-knowing where mind and matter, subject and object, are divided in the same manner as culture and nature (Latour 1993, 13-18, 112; Liodakis 1997, 70-71). Bruno Latour makes the point that Western modernity has a tendency to purify phenomena as belonging to *either* nature or culture (Latour 1993, 13-18, 112). I argue that machine technology is purified *by mainstream discourse* into being 'only' nature, since its social aspect is quite invisible, e.g.

25 My translation.

the fact that digital technology relies on exchange rates and extractivism (Hornborg 2017, 94-96). Purification can therefore be seen as normalizing the exemption of technology from social critique, since it classifies the machines as belonging *solely* to the domain of nature.

Reductionism

Dualism can be seen as the mindset on which agricultural science is based, but how the domain of nature is *dealt with* also reproduces dualist and instrumental thinking in the current Danish agricultural scene. Western agricultural science is reductionist in the way that it has sought, since the 17th century, to break down the objects under investigation, e.g. a plant or crop, into ever-smaller components. In doing so, scientists are able to manipulate the components of the epistemologically reduced and fragmented object. An explicit example of this is found in a recent report from USA, which predicts the development of farming and technology in the future: "It is a world where farming is no longer controlled as a complete unit or a series of large areas or soil areas. Future farming will instead be controlled on the level of the individual plant"[26] (IDTechEx cited in Bjørn-Hansen 2016). This reflects reductionism in a very tangible way. Reductionism has allowed manipulation of nature for human gain in general and agriculture serves a good example of this. According to Lyons and Lawrence, science that echoes Bacon's idea of mastery coincides with a capitalist mode of production and has strengthened the idea of modifying nature's mechanics for increased gain, providing a foundation for technocratic decision-making. By reducing the objects of nature, it is possible to extract increasing wealth from it by applying technological solutions for modifying and optimizing nature's components (Lyons and Lawrence 1999, 1-2; Juhl 2015). Think of the immense interest in data:

> It is knowledge that builds on experience and historical data and statements. New technologies and methods of *exploiting data* are therefore increasingly used in agriculture. This includes e.g. Ipad, internet technology and GPS. As an example, there are GPS tracking systems installed in modern harvesters. They tell the farmer which route on the field is the most *optimal* when crops are harvested.[27]
>
> (DTU 2015, 14, my italics)

[26] My translation.
[27] My translation.

The more we can know about every little cog in the machinery, the better we can exploit it. It is analogous to lubricating a machinery; if you get oil into every little corner, the smoother it will run. The quote above from the report 'Big Data: Fra jord til bord'[28] exemplifies this reductionist approach to farming. It mentions what agricultural knowledge is and how it should be used: exploitation of our knowledge, i.e. data, optimizes production.

Enchantment of technology

Along with these ideas, a disenchantment of nature has occurred. Mysticism and religion used to be an integral part of everyday life in the world. But during the Enlightenment, mysticism and religion were pushed aside as governing values in favor of a rational, bureaucratic, and scientific understanding of the world. In the disenchanted world no mysterious powers are at work and everything can be explained (Verma 2016, 130-134). Several great thinkers had something to say about this process and about whether it was a positive, negative, or neutral process. Weber thought of it as having both positive and negative effects, one of the negative being a loss of sacredness, wholeness, the link between the self and the world, and creation of meaning. Habermas, on the contrary, saw it "as humanity's liberation from superstition and ignorance, from enthrallment to nature and to arbitrary power" (Szerszynski cited in Verma 2016, 130). Technology's capacity to rationally understand and use nature's mechanisms is a good example of disenchantment. But, as Verma (2016) asks in her study, still it seems that technology itself amazes us and fills us with wonder – are we not enchanted by technology itself?

Enchantment and disenchantment are not mutually exclusive. Rather than completely removing wonder and mysticism from human-nature relations, technology changes its character. On one hand, the scientific findings facilitated by technology keep amazing and astounding us in a range of ways that are different than what nature perceived as calculable resources can do (Verma 2016, 133). On the other hand, technology itself induces wonder and awe and behaves in irrational and mystic ways. The "discourse of wonder draws our attention to new technology, [...] less as something that performs a useful task than as something that astounds us by performing in a way that seemed unlikely" (Gunning cited in Verma 2016:149). I argue that enchantment of technology goes hand-in-hand with Hornborg's idea of magic machines in the way that it strengthens the belief in their efficacy and magical properties. Machine technology works like magic because its efficacy is dependent on people's belief in its power and exogenous character. We *expect* to be amazed by

[28] Translates: Big Data: From soil to table.

technology, as is exemplified during the conference by Maria Reumert Gjerding's comment: "you become excited by what technology is able to do."[29]

Concluding on the history of ideas that has positioned Western science where it is today, I argue that nature is thought of as instrumental and mechanical. Optimizing is therefore done by engaging with ever-smaller components of it, which is exactly what ag-tech is perceived to do. The idea that nature should be known, used, and mastered purifies, in the Latourian sense, and *naturalizes* technological endeavors. This naturalization can be seen as part of exempting machines from critique since they are part of the greater undertaking of humanity: the mastery of nature. Perceptions of nature thus feed machine fetishism. These ideas implicitly permeate agricultural policy and political decision-making and are thus part of a greater discourse. Western dualism and reductionism is part of the historical context out of which the current discourse has grown. Seen from a CDA perspective, they are explanations, or social structures, through which we interpret and process descriptions, or texts, which the next section will do.

One could take many paths to shed light on the interrelations between agriculture, economy, environment, and society from a dualist and reductionist perspective, but this thesis focuses on the role of technology's modification of components of nature in order to extract wealth by increasing productivity or efficiency and reduce environmental impact. Staying with the Danish case, the next section will take a look at the discourse of technology that pervades policies and recommendations stemming from various institutions involved with Danish agriculture. This will be seen through the lens of machine fetishism. Amongst these institutions are the Ministry of Environment and Food, Danish Agriculture and Food Council, Ministry of Economic and Business affairs, and various political parties and companies/organizations involved in research, innovation, and development of ag-tech.

Danish discourse on technology

Yesterday[30] when I came home after a day full of looking at ag-tech on company webpages, I looked at my smartphone and its Facebook-app. One of the first things popping up on the screen was a sponsored Facebook advertisement for an ag-tech company that promises to save me money by reducing my use of fertilizer and chemistry. Ironically, once could say that Facebook's algorithm technology provides me with sources from which to criticize technology. The advertisement states

[29] Field note, 09-02-2018.
[30] 19-03-2018.

that FieldSense is easy and cheap and will make my use of fertilizer optimal while increasing my income. (See appendix 2.) The product is an app and online platform that analyzes precision farming data for a farmer who "wishes to achieve more with less" (FieldSense n.d.). Many documents and websites closely related to ag-tech portray technology's ability to achieve more with less (FieldSense 2018; MFVM 2016; Natur- og Landbrugskommissionen 2013; GUDP 2017; NaturErhvervsstyrelsen 2016; Klimarådet 2017; Teknologisk Institut 2015; DTU 2015). Hornborg (2013, 10) writes that "significant aspects of the functioning of technological systems rely on beliefs about their efficacy." With this he points out that the way we regard technology and its capabilities is largely a matter of faith. We believe in technology's ability to save agriculture from crisis. There must be faith that it can optimize production and make the economy grow while reducing environmental impact. It is perceived as a cornucopia, a physical entity that is productive in itself (Hornborg 2013, 10).

I attended the conference mentioned in the introduction called 'Precision Farming: Can technology replace environmental requirements?'[31] on February 9th, 2018. The list of attendants was long, ranging from the Danish Agriculture and Food Council over educational institutions to small ag-tech companies and farmers, and hosted by the Ministry of Environment and Food. The conference can be said to have gathered quite different actors in the agricultural sector. It is clear that the purpose of the conference was not to debate whether we *should* use new ag-tech or not, but rather how and how fast we can get going.[32] I see the discourse on technology apparent at the conference as a condensed form of a general discourse amongst political actors who advocate for ag-tech. It was condensed in the sense that many aspects of technology had to be covered in a single (yet long) day and in the sense that it served as a political arena where the aim was not to debate, but rather to *persuade* doubtful actors that ag-tech is the future of Danish farming.[33] Below I outline three aspects of political discourse on technology stemming from political actors. This is based on material from the conference and publicly available information.

[31] Danish: Præcisionslandbrug: Kan teknologi erstatte miljøkrav?
[32] Fieldnotes, 09-02-2018.
[33] Fieldnotes, 09-02-2018.

Make haste

Competition is mentioned countless times in various documents and during the conference (MFVM 2016; Erhvervs- og Vækstministeriet 2015). The minister was part of a panel at the conference along with Maria Reumert Gjerding, spokesperson for the environment from Enhedslisten,[34] and Martin Merrild, chairman of Danish Agriculture and Food Council (DAFC). Here it was stressed by all parts that we should get going, putting technology to use. It seemed as if things were actually moving too slow. A question was posed from the moderator: the incorporation of new technologies, how urgent is it? The three panelists nodded enthusiastically, smiling. Gjerding says that we should get going as fast as possible due to the environmental benefits. Larsen stresses that competition on the market calls for hasty action. Merrild agrees and mentions that machines are cheaper than ever and that we should get going. It seems as if we could get started already during the conference.

I argue that haste can be seen as a built-in factor in the growth paradigm governing decision-making. Denmark is part of the global food market, where competition is constant. In order to stay ahead in the growth race, one should make haste and invest right away. Underlining that technology provides environmental benefits serves as the persuasive factor that makes its application an undeniably good thing. It also presents a good example of the political innocence of technology, since three very different actors, surprisingly, agree on technology's abilities. Making haste to adopt new technology is part of carrying out a political scheme of growth and competition and is presented as a necessity for staying economically afloat, and the argument is 'brought in' to the area of politics.

Do not get in the way of progress

Another discourse element is the notion of progress. Much of the new technology discussed at the conference and mentioned in news articles (e.g. Bjørn-Hansen; Poulsen and Skov-Jensen 2017) has not yet been put to use but is still being developed. But when Merrild said at the conference: "New technology? Yes! We have to try it!",[35] he refers to technology as a concept. Even though the specific technology might not even be ready yet, he advocates for the use of it. This shows that the *belief* in technology that Hornborg (2013) mentions is part of what will catalyze investing in and adopting new ag-tech. Merrild, who is chairman of possibly the most influential interest group in Danish farming, testifies that he himself used to be against progress in the form of methods and

[34] A left-wing political party.
[35] Field notes, 09-02-2018.

technology, but that he now believes in its efficacy. It has almost a religious aspect – he left skepticism behind and was embraced by the goodness of ag-tech.[36] Larsen explains that he imagines that everything will be monitored with drones and the like in ten years. Effective technology is "right around the corner"[37], says a representative from one of the leading developers of high-tech solutions, AGROINTELLI, when asked if the current technology actually works. This underlines that belief in it is important. News sites reinforce this discourse: "One thing is sure. Automatization is on its way. And the robots are already here" (Bjørn-Hansen 2016). This implicates that people are enchanted by the great technological potential waiting to be tapped. Technology has almost religious connotations in that farmers are told to prepare for the advent of a 'savior' in the form of the techno-fix that can help Danish agriculture out of crisis by sustainably growing the sector and providing a stronger basis for global competition. It is imperative to believe in technology so that one will not stand in the way of progress, and progress must be reached with haste. Though its efficacy might not be completely clear now, it is 'right around the corner'. Non-believers are simply slowing down the progress of Danish agriculture as a whole.

Incredible machines

Perhaps the most significant aspect of technology discourse is how the enchanting capabilities of technology are presented. During a meeting hosted by DAFC called AgTech Day,[38] the message from the host was that ag-tech is a condition for a strong agricultural sector and that it is part of the fight to stay ahead in international competition. The AgTech Day was an event for Danish ag-tech companies to meet, network, and organize under a common banner (DAFC). That DAFC invites tech companies to join them can be seen as a clear expression of the increased focus on ag-tech and its perceived importance for future agriculture.[39] It is important due to its capabilities:

> Overall, there are three ways to reduce agricultural emissions. You can produce something else, produce less, or invest in technologies which can reduce emissions without changing the scope of the production.[40]
>
> (Klimarådet 2017)

[36] Field notes, 09-02-2018.
[37] Field notes, 09-02-2018.
[38] Danish: AgTech Dag, Copenhagen, 10-01-2018.
[39] Field notes, 10-01-2018.
[40] My translation.

Thus writes the chairman of the Danish Climate Council on their webpage. Producing less does not really fit well with economic growth but changing what we produce is challenging for both economic growth and exports, since e.g. Danish pig meat is well-renowned abroad (Landbrug and Fødevarer 2017, 11). Though he believes that all three ways must be chosen to some degree, it is interesting how technology might fix the emissions problem *without* lowering the scope of production. Besides reducing emissions, technology also offers economic benefits.

"EcoBotix wants to offer the greener path – be the golden opportunity for growers" (EcoBotix 2018). Thus reads a sales pamphlet from a company providing a drone solution for pests in organic production. Benefits come in multicolor, green and golden, environmental and economic. At the conference, the minister of environment and food, Larsen, expressed that the more technology, the better it is for intensive agriculture. He explained that there is a connection between a farmer's brain and his wallet and that future governmental requirements for using the new technology are very likely. The future economic benefits serve as a good motivator for using it now. Later he states that technology should be used to honor environmental requirements.[41] This implicitly answers the question posed in the title of the conference: yes, technology can replace environmental requirements, since it is a multicolored win-win investment – for the environment and the wallet. Reading between the lines, I argue that it is belief in this magic cornucopian effect of ag-tech that *enchants* its advocates.

According to presentations at the conference, other things that technology is capable of include that sensors and computers can do much of the farmer's work, which will liberate time for doing other things, and create value in society by creating value for agriculture, nature, and tech companies. 81% of the conference attendants agreed that precision farming is a necessary condition for a greener environment.[42] In general, the green-golden win-win attribute of technology pops up in almost every context where ag-tech is advocated for (Landbrug og Fødevarer 2017, 34-37; MFVM 2016, 19; Natur- og Landbrugskommissionen 2013, 14; GUDP 2017, 3; Teknologisk Institut 2015, 39-44, 71-74).

In conclusion, it can be said that agricultural discourse is informed by an instrumental, reductionist, and Western way of perceiving nature. Technology can be regarded as a method of optimizing the mechanics of nature by modifying its parts. Nature is thus made more efficient and hence provides

[41] Field notes, 09-02-2018.
[42] Field notes, 09-02-2018.

a condition for economic growth. Digital technology gathers large amounts of data that enable a farmer to optimize her activities, saving money and also saving the environment. Technology is perceived as socially exogenous machines that are intrinsically and in themselves capable of optimizing production. The technology discourse presented here contains different elements that are part of the worldview reproducing machine fetishism. First, there is a discursive imperative that Danish agriculture should move with haste and adopt and develop new technologies because of the need to grow and stay competitive. Technology is perceived to optimize production. Second, no one should question technological progress so as not to stand in the way of the hasty progress that Denmark needs. Instead, people should believe in the efficacy of technology. Third, digital technology is perceived as incredible and enchanting, meaning that it magically can provide economic growth by optimizing production without compromising the environment. The digital machines appear to be productive because of their relation to nature which is essential to machine fetishism. This approach mystifies the underlying but obscured social relations of the machines that are part of what makes the technology possible. The next chapter of this paper will deal with these social relations of digital technology and make the case that they also have underlying and mystified environmental relations. It will investigate the relations that are mystified through fetishism and what makes digital machines possible in Danish agriculture. It looks at the very materiality of technology and the conditions for the emergence of digital ag-tech as well as its consequences.

IV

Rare earth elements in the world system

Introduction

> Before the factories were built, there were just fields here as far as the eye can see. In the place of this radioactive sludge, there were watermelons, aubergines and tomatoes.
>
> Resident of Baotou, Li Guirong in The Guardian (2012)

Technology is made of *something*. As mentioned in the introduction, an investigation has shown that an iPhone 6 consists of *at least* 30 different elements of the periodic system. They include cobalt which is mainly mined in DR Congo. Mines in Congo reportedly use hazardous methods and child labor (CompoundChem 2014; Zetland 2017). This is not something we normally think about when interacting with the world through our small screens. The point being that our modern-day technology is made of elements which have to be extracted *somewhere* and by *someone*. Digital machines used in agriculture are no exemption, but we tend to forget this in our machine fetishism. This chapter will look out into the world and investigate the mystified socio-environmental relations of our digital machines.

The town of Baotou in the Inner Mongolia region of China became the center of mining operations in the 50's, which caused the city to grow rapidly due to the economic upswing associated with the mining. But eventually a darker side of the economic boom started showing its grim face. Fields and livestock in nearby villages died off, villagers started coughing when inhaling dust created from mining and refining the ore. Waterbodies were contaminated, and villages were abandoned. Farmers either fled or got a job at the mining company. The visually strongest representation of the whole process is a 'tailing pond'[43] created from the mining operation which is still in use. The 'pond' is actually more like a large toxic lake close to Baotou. Reportedly its size is 11 km^2. The lake is filled with the residue from the mining operations, called tailings. Nothing really lives in the lake when acidic wastewater and radioactive material pours into the lake at the rate of 2000 tons of tailings per ton of minerals produced (Filho 2016, 271-272; Bontron 2012; Maughan 2015). It has been described as a "dystopian lake filled with the world's tech-lust" (Maughan 2015) and its dark and gloomy appearance brings to mind the land of Mordor in *The Lord of the Rings* - see appendix 3. What is mined are rare earth elements (REs) that are crucial to modern technology.

What are rare earths?

Rare earth elements are 17 chemical elements in the periodic table. They are naturally occurring in the ground and are not particularly rare, but rather, most are quite plentiful across the planet. Some argue that the name 'rare' comes from earlier times where the word signified something strange or extraordinary. They include:

> scandium (Sc, atomic number 21), yttrium (Y, 39), and the lanthanides, which are lanthanum (La, 57), cerium (Ce, 58), praseodymium (Pr, 59), neodymium (Nd, 60), promethium (Pm, 61), samarium (Sm, 62), europium (Eu, 63), gadolinium (Gd, 64), terbium (Tb, 65), dysprosium

[43] Tailings are residue of mining ore.

> (Dy, 66), holmium (Ho, 67), erbium (Er, 68), thulium (Tm, 69), ytterbium (Yb, 70), and lutetium (Lu, 71).
>
> (Zepf 2016, 3-4)

They never appear in a native state, i.e. as 'nuggets' in the ground, like you imagine gold, but rather they are always combined with other elements. They therefore need to be separated from the other minerals (Zepf 2016, 4-7). First, the ore must be extracted by mining, then separated into what is called REOs, which is rare earths bound to oxygen, then refined into REs which is the pure metal state. The whole process is very demanding and includes various chemical processes (Massari and Ruberti 2013, 36-38). Once extracted, separated and refined, REs are used in a wide range of applications, e.g. electronics, automotive, nuclear and oil industries as well as green technology. Important to this paper and their connection to digital technology is the fact that they are critical to much modern technology and are widely used in green energy technology (e.g. efficient lighting, wind power), electronics such as optical lenses, display screens, electric motors, lasers, hard disk drives, mobile phones, high-capacity batteries, metallurgy as well as various components for electronics, e.g. superconductors and magnets (Massari and Ruberti 2013, 41-42; Filho 2016, 269). Basically, they "are indispensable or at least necessary for high-technology applications, lifestyle products, and products and systems that guarantee the changeover to a low-carbon energy society" (Zepf 2016, 10). As an example, an iPhone 6 contains eight different REs (CompundChem 2014). In 2014, some 110.000 tons of REO (the state before refining) is produced globally out of which 90% were from China. Around half of China's total production comes from the Baotou mine (De Medeiros and Trebat 2017, 513; Filho 2016, 270; Zepf 2016, 8; Kaiman 2014).

Socio-environmental impact

"Mining leads to encroachments on nature and requires energy, fuels, and chemicals, which have to be remediated accordingly. If this is not done properly, environmental damage is inevitable" (Zepf 2016, 9). RE-mining, like other mining, has consequences and different social and environmental impacts have been and are still connected with it. Since REs and radioactive elements are often found together it requires serious measures to protect environment and workers. Mitigating environmental and human consequences is expensive and requires large investments, which is partly why many mines and deposits remain unused. It is simply too expensive (Massari and Ruberti 2013, 42).

> According to the Chinese Society of Rare Earths, 9,600 to 12,000 cubic meters (340,000 to 420,000 cubic feet) of waste gas—containing dust concentrate, hydrofluoric acid, sulfur dioxide, and sulfuric acid—are released with every ton of rare metals that are mined. Approximately 75 cubic meters (2,600 cubic feet) of acidic wastewater, plus about a ton of radioactive waste residue are also produced.
>
> (Earth Observatory 2012)

A quick calculation reveals that in 2012, when the abovementioned waste calculations were made, China alone, producing approximately 95.000 tons of REs[44], released some staggering 190 million tons of tailings (Filho 2016, 272) which contained roughly 912-1.140 million cubic meters of waste gas, 712.000 m^3 of acidic wastewater and 95.000 tons of radioactive waste residue.

The tailings of RE-mining contain hazardous waste material including chemicals, radioactive particles, wastewater and toxic levels of various material, e.g. salt. The mine in Baotou has, after 40 years of operation, left around 11 km^2 of these tailings, which has contaminated the soil, groundwater and vegetation of the surrounding area. Dusts and aerosols are created from mining that spread with the wind. They can be irritants, toxic and carcinogens and pollute the surrounding area. Plants and farming are affected as well. Plants absorb REs from soil through the roots and investigations have shown that plants in mining areas contain up to 10-20 times the nationally set limit of contaminants. Farmers report that their crops withered away or produced small and toxically odorous fruits after mines were established. The soil was contaminated and farming made impossible. Families depending on farming were thus forced to move or change their occupation (Filho 2016, 271-273; Bontron 2012). Surface and groundwater are polluted with impacts on aquatic ecosystems as well as posing threats for humans. It was partly due to groundwater pollution that the Mountain Pass mine in the USA, closed down since they had issues with assuring a safe mining procedure. Some of the direct health impacts recorded are bioaccumulation and negative effects on the respiratory system (Filho 2016, 274-275; Rim 2016, 196-197; Massari and Ruberti 2013, 42). The Guardian reported in 2014 how the villages surrounding Baotou experienced polluted drinking water, that livestock died, and crops that withered. A resident said that most neighbors have moved away and seven have died of cancer. In 2009, the mining company started relocating villagers to outskirts of the city, further away from the tailings (Kaiman 2014). Though China has made efforts

[44] See appendix 4. That table shows circa 92.000. Other reports states that they produced approximately 100.000 tons (Long 2012), therefore 95.000 seems a reasonable estimate.

to reduce the impact of RE-mining, there is still a long way to go (Kaiman 2014; Klinger 2018, 3; Filho 2016). As Ma Jun, director of the Institute of Public and Environmental Affairs told The Guardian in 2014; "we [China] basically export the resources at a rather cheap price, and much of the environmental cost is externalised [*sic*] to local communities" (Kaiman 2014). Klinger (2017a, 3) estimates that around *two million* people globally are prone to epidemiological crisis due to living downstream from water pollution or in the area close to former or on-going RE-production. This is especially common in northern China, southern California, Malaysia and Central Asia.

The link between ag-tech and rare earths

> Governments thus far have failed to provide sufficient certainty to support investments in environmentally sound rare earth production, while major downstream buyers have opted not to purchase more sustainably produced rare earth elements.
>
> (Klinger 2018, 3)

The road that REs must travel to reach Danish fields is long and complex, from extraction to refining and onwards to integration into components that are again integrated into other components until it ends up in a digital technology. It might have traveled through several countries and companies. I reached out to 11 important Danish companies[45] that use various digital machines in their ag-tech products. None of them could ascertain whether or not their products contain rare earths – they just buy a component, robot or other hardware from other companies located across "the entire world", as one puts it. Most of them had never heard about REs. When they buy components and hardware they trust that their suppliers take required measures to ensure quality. Only one had knowledge of more than the first link in the supply chain of a component, e.g. where a supplier of a GPS-controller acquires the battery-component for it. But two links are still just a fragment of the entire supply chain. A project leader of a large collaborative precision farming initiative puts it the following way: "we just focus on whether or not the technology works. Sustainability will have to come later"[46].

[45] Not included here are one of the major actors did not want to participate, and two from whom I could not get a reply.
[46] My translation.

A Danish magnet producer (a magnet is a component) who caters to the agricultural sector explained that since around 90% of REs come from China so does around 90% of the REs they use for magnets. It should also be taken into consideration that all the ag-tech software that is developed rely on digital technology such as computers, for its production. Also, much of the software is used on a farmer's own computer or smartphone. Therefore ag-tech extends itself quite wide-ranging into the area of consumer electronics, e.g. computers, tablets and smartphones. Whether REs are used in small or large quantities in ag-tech is difficult to determine, but the increasing *future demand* of quantitively more and increasingly efficient technology and its connection to other than agricultural technology nonetheless calls for a critical review. Due to the growth imperative in Danish agricultural policies, technological advances will not stagnate, but will continuously have to increase efficiency in order to make the agricultural sector of Denmark competitive. Though digital technology does not *per se* contain REs, one should suspect that much of it will eventually do so, due to the capabilities of REs in producing much more efficient technology (Zepf 2016, 10). The mystification of technology's dependency upon social and environmental relations exempts the currently used technology from critique and could *potentially* clear the way for heavy RE-use in ag-tech.

Some would argue that I should have focused on consumer electronics or green technology, i.e. information, communication, solar and wind technologies, since these industries undoubtedly require quantitively more from the RE industry. Despite the quantitative issue, I have chosen to focus on digital technology in agriculture due to several reasons. First of all, Danish agriculture is in search of new directions, e.g. precision farming and the so-called moon pig project, whereas political and scientific discussions rarely emphasize the actual digital technology. Setting direction for the entire sector should be done on a well-informed basis. Second, I believe that smartphones are such an integral part of many peoples' lives that it is hard to let go of them, despite the knowledge of their impact. With agricultural technology, there is still the choice, and the discussion, whether Danish agriculture *should* use more digital technology and what kind of technology we will use in the future. The smartphone, on the other hand, also has a role to play in ag-tech as mentioned above. Third, the darker nuances of green technology are already in focus among researchers and journalists (see Zhou et al. 2017; Barteková 2016; Habib and Wenzel 2014; Zetland 2017) and instead of repeating their arguments this thesis will add the case of agriculture to the discussion. Though it without doubt is a quantitatively larger issue for both consumer electronics and green tech, a critical approach to the use of REs should not exempt the agricultural sector. After all, Danish agriculture stands before a crossroads with several options. Taking the road that seems easiest and most straightforward to begin with might end up bringing us completely off course. It is more likely to choose the better road if one considers with what it is paved.

Chinese dominance

China is by far the largest producer of REs in the world. The country produced around 90% of the global supply in 2016. The Danish magnet producer mentioned earlier explained that even in 2018, since China still dominates RE-production, around 90% of the REs they use are from China. The country's dominance peaked in a de facto monopoly in 2010 when production reached 97% of global REs (Filho 2016, 270; Klinger 2018, 2; Mayuko 2017).

The reason why a monopoly could be established was the historical emergence of RE-production. When exploitation of REs began in the 1950s, there were mining projects in various regions, e.g. the Mountain Pass mine in USA, but many closed down due to competitive production in China. The labor cost in China can be kept very low relative to other RE-producers and the country has a large labor force (Grell-Brisk 2017, 9). Along with the low wages there is another factor that serves competitiveness; most of the mines were at the time unlicensed and unregulated, making mining even cheaper, since they did not need to honor specific environmental, health or social requirements (Massari and Ruberti 2013, 37; Grell-Brisk 2017, 9). Therefore, China simply extracted REs cheaper than anywhere else.

In the late 2000s, and especially during the 2010 monopoly, China halted exports of REs by creating quotas. An additional RE-tax was also introduced. The result was that in 2010 export quotas were cut by 40% and a consequently significant market price boost of REs happened due to supply and demand factors (Klinger 2018, 2-3; De Medeiros and Trebat 2017, 520; Kalantzakos 2018, 3). The export halt became a WTO-case.

> China argued that they had to solve severe environmental problems that occurred during REE [*sic*][47] mining and processing. Dispute settlements brought forward to the World Trade Organization (WTO) by the US, Japan, and Europe against this argument and against the Chinese practice of export restrictions were partially granted (Zepf, 2013). As a consequence, China

[47] Another abbreviation for Rare Earth Element.

> withdrew the export quota in the beginning of 2015 and abolished the export taxes as of May 1, 2015. Instead, a new RE resource tax was introduced to replace recent policies.
> (Zepf 2016, 13)

After the complaints from several countries to WTO, China had to abolish the export halt, but had already then increased the market price of REs. Also, prices on certain REs have been boosted further during recent years due to high demand from especially electric vehicles (Richie 2017). The shock of the export halt and increased price and demand led importers to speculate in re-opening the large Mountain Pass mine in USA and to explore and work towards possibilities for mining in various places, including Greenland, Afghanistan, the Amazon, in deep oceans and on the moon. These are on-going projects that raise social and environmental concerns among experts (Klinger 2017a, 3; Filho 2016, 275-276). Despite even stricter environmental requirements and higher labor prices than in the early days of RE-mining, it is again deemed a lucrative and competitive industry. But it still is an industry extremely costly to establish (Kharunya 2013). I argue that playing part in increasing global demand for REs, also when seeking other suppliers than China in order to secure a more sustainable production, is feeding new extractivist ventures, on land, in the sea and in space, which raise socio-environmental concerns. Denmark's demand for REs is inevitably global in character as long as we do not mine nationally.

China in the world system

China's role in the world system of production and trade with RE is significant. Having indicated the connection between the mines in Inner Mongolia and modern digital technology used in Danish farming, it is important to take a look at how this complex system of international trade and production function, i.e. the character of the mystified relations of technology.

Following Wallerstein's world-systems analysis, China arguably used to be a peripheral country that supplied natural resources to core countries that added value, viz. produced technology. But in the third millennium, China has arguably risen to a semi-peripheral position. In the 90s the trimodal world system (core, semi-periphery, periphery) saw the majority of the world's population belonging to peripheral areas, and a small minority to the core. But according to Grell-Brisk (2017), the shape of the system changed during the following decades as China slowly moved into the semi-periphery, as determined by GNI per capita. See appendix 4. Most of the world's population thus shifted from periphery to semi-periphery. This challenges Wallerstein's assumption that the capitalist world system requires a large periphery and a smaller semi-periphery (Grell-Brisk 2017, 2-9). China started producing technology more intensely between 2000-2007 and thereby adopted what had previously been the task of core-countries to which China had exported the raw materials (De Medeiros and Trebat 2017, 505). I will add that the export halt of 2010 obviously did not affect China's own production of technology, as it could access REs domestically and thus establish a more solid domestic system of production possible. Furthermore, China has good connections with many peripheral areas which can provide further resources for its production, thus acting as an exploiter, but applying 'soft-power' (Grell-Brisk 2017, 8). Heavy economic growth and increased military spending further cemented its semi-peripheral position during the 2000s. State-based capitalism and the Chinese wage-level, which had benefitted foreign companies exploiting the country's work force became very advantageous to the emerging productivity of China in the area of technology (Grell-Brisk 2017, 7-10).

China's dominance as regards REs and its transition into the semi-periphery can be said to have established new structures reminiscent of unequal exchange. Through unequal exchange core countries have been able to import REs for production of high-technology that have increased economic and environmental efficiency in these countries, just as digital technologies are believed to make Danish agriculture more environmentally sustainable while generating growth. Following Hornborg, I argue that the saving of time (labor, e.g. by means of self-driving tractors) and space (land, e.g. by means of higher yields through the monitoring of pests) *saved* by technological efficiency in core countries only occurs on the *expense* of time (labor, e.g. extraction, refining, production) and space (land, e.g. mines) elsewhere in the world (Hornborg 2013, 18-20). The appropriate concept is environmental load displacement. While core countries gain 'clean' technologies and environmental improvements, the 'dirty' industry behind those technologies is located elsewhere geographically and causes environmental degradation. Instead of reducing absolute impact on environment the impact is rather *moved elsewhere* (Wan and Wen 2015, 158). This seems to be the case of digital technology used in core countries. It might reduce environmental impact in e.g. Danish farming, but it will indirectly increase environmental impact in Chinese mining since the use of digital technology intensifies the RE-mining industry.

Unequal exchange between core and periphery has been pervasive historically, but as already noted, the world system has changed. I argue that the export halt of 2010 can be seen as a symbol of China's rise to power and its challenge to the trimodal world order. Unequal exchange is thus made even more complex and goes beyond trimodality. Wallerstein (1974) argued that unequal exchange is true for geographical areas and not only nation-states. I argue that it happens *within* China, where the losers are the local, geographical areas and communities and the environment affected by RE-mining, and the winner is China as an increasingly semi-peripheral, political state. The state wins by shifting parts of unequal exchange from a relation between core and peripheral countries, to an internal relation *within* an emerging semi-peripheral country. This challenges the trimodal world system described by Wallerstein because China, as semi-peripheral, is able to challenge the power of core countries, thus influencing global extractivism. A quadri-modal or even a completely different modality of the world is needed to explain China's unconventional semi-peripheral position. The RE example can therefore be seen as an expression of a changing world system, in which core areas of China are engaged in unequal exchange with peripheral areas inside the political boundaries of the country itself. This exchange influences the world system and China should therefore not be seen as 'just' a semi-peripheral state. The situation is more complex, and the trimodality described by Wallerstein comes short in explaining it.

It should also be noted that when China challenges the world system by becoming core-like in its activities it has spawned a Western critique of China. In the time after the export halt of 2010 both a popular video-game and movie[48] featured an 'evil state' that keeps minerals to itself and news stories told exaggerated stories of the importance of REs, stating that China was the only state with access to the mineral (Klinger 2018, 3-5). I would therefore also argue that modern technology exists through a system of unequal exchange and production and that challenging the order of the system influences popular culture. The relations in the system are biasedly reflected in movies and video-games, strengthening discourses on evil states and dependency on free trade in certain resources. Though the export halt was taken to WTO trials, it seems almost hypocritical that the former exploiters, when faced with competition from the formerly exploited, are quick to paint the picture in a core-favorable way.

The future of rare earths

In 2018 the export halt lies some years back, but China still dominates the market. As mentioned earlier new explorations into RE-mining are being conducted in order to break the monopoly, meet demands and supply the world with the minerals needed for a highly technological future. But what

[48] Video-game: 'Call of Duty: Black Ops II'. Movie: 'Avatar'. Also, one of the minor plots in 'House of Cards' featured tense China-US relations over REs, portraying China as the state sitting on all the minerals (Klinger 2018, 4).

does the future of REs and technology look like and, more importantly, how *could* it look? Investigating the underlying structures of what appears to be simply a matter of integrating new digital technologies into Danish farming, as this thesis have done, helps us to both shed light on the conditions for technologies to exist and to highlight areas where action could be taken to reduce the negative consequences of technology. REs are a contested field politically and many interests are at stake. "Understanding these interests is important to building a more efficient, sustainable, and just rare earth economy" (Klinger 2018, 2).

Recycling, substitution or simply decreasing demand by relying less on them all are approaches to a more sustainable production of REs. As it is now, less than 1% of REs are recycled (Habib and Wenzel 2014, 352; Klinger 2018, 2). Certain initiatives are in work, but none have really proven worth it, economically speaking. According to the Danish magnet producer no one has been able to recycle the neodymium magnets which they produce[49]. The global production of neodymium magnets was estimated at 78.000 tons in 2015 (Benecki 2013). It seems that finding substitute elements is almost impossible and that if substitutes were found, it would probably just move the same problems to other parts of the world or create new ones (De Medeiros and Trebat 2017, 510; Klinger 2018, 3). Klinger (2017b, 237-240) lists three areas in which efforts could lead to a more sustainable RE use; the politics mining must be made explicit, i.e. open for critique. Social movements and research results needs to be taken seriously, and the claims made by states and companies must be reviewed. Secondly, the market must be pushed towards more sustainably produced REs by the means of certifications, tax incentives and increased monitoring. Lastly, recycling could help minimize production and incentives for new RE explorations. These are all areas that could potentially make the industry more sustainable. Approaching RE production in this way assumes that demand *will* increase and that the industry *naturally* has to fulfill the need. The question becomes how we fulfill it properly. Though it is very realistic to assume that demand will increase, the solutions proposed come from within a world system of market and production, in which growth, and therefore an ever-expanding production, *must* occur for the entire system to function. What would happen if demand was *reduced* and dependency on the global market *limited*? Taking the Danish perspective; the *choice* is still there whether or not to increase dependency on REs. There are other futures for Danish agriculture than depending on minerals that wreak havoc in Chinese villages or potentially in Greenland.

[49] From correspondence with a Danish magnet producer.

This thesis has presented aspects of the desired technological future of farming. These aspects, such as agricultural politics, perception of nature and discourse on technology also present opportunities for addressing the issues of the relation between digital machines and REs. By applying the critical realist triple-layered model of reality, we gain a greater insight into the mechanisms at play and how certain events are caused. By looking at the real, the actual and the empirical domains of the world system in which both Denmark and China are embedded, we can identify areas that can (or cannot) be changed resulting in large or small effects on the phenomenon of RE-dependent technology and farming. In the domain of the real are the roots of the structure, the generative mechanisms. These are transitive and intransitive structures that create the conditions for the events identified in the actual and the phenomena observed in the empirical. I have attempted to outline some of the mechanisms, events and phenomena that I deem relevant in the context of Danish agriculture, digital technology and RE-mining. Many more could be identified, but the ones presented here are related to the arguments presented by this thesis. Marked with bold are areas in which direct action can be taken in a Danish context. Providing more concrete solutions is a task for another thesis or paper. The following attempts to direct future action toward relevant and important areas.

The Real	The Actual	The Empirical
- Growth imperative **- Instrumental perception of nature** - Resource based economy - Finite planet - Global trade institutions (e.g. WTO) - World system of production	- **Technology discourse/machine fetishism** - Global trade regulations - National agricultural policies - Globalized tech production - Unequal exchange - Tech innovation - Neoliberal national economy - Discourse on importance of competitiveness - Plans for new mines	**- Increased use of ag-tech in farming** - Impact of mining on people and environment - Farming practices change - Investments by private sector and state in innovation - Agricultural crisis – the death spiral - Larger, tech-filled farms - Ag-tech collaborations

Figure 1: Real, actual and empirical

Change can occur in the different domains. If farmers decreased their use of ag-tech containing REs, it would influence the demand directly. It would be direct change in the empirical domain but requires rethinking the future of the agricultural sector since alternatives for avoiding the death spiral would have to be offered.

In the domain of the actual, 'demystifying' the machines, making them subject to critique, could be eventful change. This could be done by increasing public and political awareness of the consequences of digital machines. Another change of the actual could be new national policies that take into account the environmental load displacement occurring by using seemingly sustainable technology. The growth imperative to which Danish farmers have to abide by could also be removed or weakened by rethinking national economy or by modifying policies and laws to combat the death spiral, e.g. with modified subsidies. On a global level, new trade regulations of RE trade could limit the extraction of REs as well as securing a more sustainable and fair extraction. A concrete suggestion would be to ensure material traceability of digital technology which could change the opacity of the world system and provide transparency for tech companies wanting to avoid environmental load displacement. International trade legislation could demand an 'ingredients'-list of technology *throughout* the supply chain. This could bring transparency to the different links in the chain as well as the material composition of a digital machine. In line with Klinger's suggestion (2017b) to establish sustainability certificates for RE mining, I suggest that certificates for sustainable life-cycles and supply chains of technology could be developed. This would make it easier for companies and end-users to choose sustainable technology and to avoid REs. On a national level, legislative demands of sustainable materials in technology could be implemented. This would push companies to choose components from sustainable producers.

In the domain of the real, a change of the growth imperative governing global markets could be collaboratively changed. Changing our Western, instrumental perception of nature could disintegrate the idea of natural resources dependent growth. Though perhaps easier said than done, such changes would reverberate through all three layers as it is an underlying mechanism, causing events and phenomena in the actual and empirical.

Questioning the world system of production in which unequal exchange make it possible for Denmark to gain sustainable growth at the expense of socio-environmental consequences elsewhere is essential. We must become aware that machines are not socially exogenous and have consequences *somewhere* and for *someone*.

V

Conclusions

Danish agriculture is in crisis and sees farm after farm shutting down. Growth is perceived to be the solution and farmers are told to continuously invest in optimizing their production in order to be competitive in both local and global markets, i.e. to survive what has been called the 'death spiral' of Danish agriculture. The government's long-term strategy for Denmark and for agriculture is to create growth without compromising the environment. This was manifested in 2015 as an agricultural reform which should provide the means to create growth without further impacting the environment. Using current technology and preparing for the technological future is *believed* to optimize production in an environmentally friendly way, simultaneously enabling sustainability and economic growth. The way that digital technology is presented politically, e.g. in the reform, is part of a discourse on technology which fetishizes it by mystifying the social relations upon which the capabilities of digital technology depend, making it appear enchantingly and magically productive.

The discourse on technology presented in this thesis is informed by a dualistic, instrumental, and reductionist perception of nature. It is not a universal distinction, but a Western one. Western reductionist science sees nature as mechanical and reduces it to its components or building blocks. This is reflected in the on-going quest for data in agriculture. By modifying the mechanics, technology can enhance nature and thereby increase exploitative gains for humans. An instrumental perception of nature legitimizes exploitation for human gain, which in turn is part of the current economic system that bases itself on the principle of economic growth. Competition calls for continuously developing the exploitative capabilities in order to stay afloat economically. Danish discourse on technology is largely an expression of these concerns. Ag-tech is the solution that, without compromising the environment further, will bring economic growth by modifying ever-smaller parts of nature's mechanics, thus increasing our capacity to exploit natural resources. Technological development has long been part of increasing agricultural efficiency and overcoming barriers and is purified in the Latourian sense, meaning that the hybridity of technology, i.e. its being both society and nature, is obscured by being ascribed solely to the domain of nature. We now see the advent of digital technologies that do not require a high energy input to run and yet can replace some of the demand for human labor. One should take into consideration the amount of energy put into *producing* these effective machines. The very material substance of the machines must be produced somewhere, somehow, and out of something. The digital machines gather huge amounts of data on various aspects of the mechanical workings of nature that enable a farmer to optimize his activities, saving money and saving the environment. This is how these new technologies are presented by the industry and politically: as socially exogenous machines that are extremely good at increasing output and lessening input, i.e. creating a base for sustainable growth.

The way that technology is presented discursively by the various actors mentioned in this thesis reproduces machine fetishism. Magic, powerful attributes, and enchantment of digital technologies are part of what mystifies the social relations in which machines are embedded. Technology discourse exempts digital machines from critique since they are perceived as intrinsically and neutrally productive. They are nothing but ingenious ways of *restructuring the mechanics of nature*. This is part of why agricultural actors that are miles apart politically can smilingly agree that this new digital ag-tech is nothing but good for business and the environment. The discourse contains other elements as well. Danish agriculture is told to make haste in adopting new ag-tech since the need for growth is pressing, due to competition globally. Also, enchanting machines are said to be right around the corner with an unknown but immense potential. Farmers are told not to stand in the way of progress since there is no reason not to believe in the potential. The discourse thus reproduces machine fetishism which obscure the underlying socio-environmental relations upon which machines depend.

These relations are, among others, between the materiality of the machine and extractivism. Modern technology relies on rare earth elements (REs), of which 90% are produced in China (in 2016). They are 17 elements of the periodic system which are used to make technology more compact and more efficient in a range of ways. They are used in e.g. optical lenses, screens, electric motors, lasers, hard disks, mobile phones, batteries, and for magnetic and conductive components in electronics. The elements are regarded as indispensable to modern technology.

The extraction of REs has socio-environmental impacts. China's RE production in 2012 created some 190 million tons of hazardous waste, around 1.000 million m^3 of waste gas, 712.000 m^3 of acidic wastewater, and around 95.000 tons of radioactive waste residue. People and agriculture in the vicinity of mining are affected in a range of ways. Toxic dust and aerosols are spread with the wind. Soil, land surfaces, and groundwater are polluted, making farming impossible and destroying people's livelihood. Reports of cancer, bioaccumulation with unknown effects, and respiratory diseases have been reported. Especially the area around a Chinese mine in the Inner Mongolia region has been severely affected, but around two million people may be affected globally, in many places due to living downstream from mining sites.

The link between Danish ag-tech and rare earth is difficult to establish in quantitative terms, but even so, the link is important, due to several factors: 1) REs are crucial to modern technology. 2)

Future demand for advanced technology will increase since Denmark wants to technologize the agricultural sector. 3) Ag-tech software used with digital machines is connected to certain consumer electronics which also rely on REs. 4) Danish ag-tech companies do not know what their technological products contain, rely on opaque supply chains, and are not concerned with the material 'ingredients' of the technological solutions they offer. 5) The world system of production is opaque and complex, making it hard to ascertain if a machine contains REs, and to what extent. 6) Even though the quantitative use of REs might be small in the agricultural sector, compared to e.g. consumer electronics, the sector still has the choice to limit its demand of REs, to demand sustainably produced technology and transparent supply chains, and to seek other ways of optimizing production. 7) Denmark does not produce REs, and many of the components used by Danish ag-tech companies are produced abroad. When digital machines appear to magically ensure economic growth and environmental sustainability in Denmark, it is partly due to a world system of production and extractivism.

RE extraction revolves around China, who is the main global producer. China has been able to dominate RE production due to low wages and lax environmental requirements. By applying world system analysis, it can be said that China has moved from the periphery into the semi-periphery. The semi-peripheral role of China is complex: by providing REs for the country's own technology production and by maintaining soft-power relations with peripheral countries for other materials, China challenges the traditional trimodal world system structure which has historically relied on unequal exchange between core countries and the semi-periphery/periphery. Core countries have thus been able to displace their own environmental impact to other places in the world, e.g. by using Chinese REs for technology. Though technology might reduce environmental impact in Denmark, it might also increase environmental impact elsewhere. Since China established its own technology production, the country has challenged core countries, but also created structures reminiscent of unequal exchange *within* itself. The mining areas serve as peripheral areas while the Chinese state acts as the core. The world system of technology production is thus more complex than Wallerstein's trimodal world system. China's dominance of REs by internal unequal exchange has influenced the world system of production by increasing RE prices and by monopolizing trade. It is therefore now deemed lucrative to open up new mines and for core countries to challenge Chinese dominance in the production of REs. Mining projects in e.g. Greenland, in the sea, and on the moon are underway. Seeking less expensive or more sustainably produced REs than the

Chinese might therefore prompt new extractivist ventures that also raise socio-environmental concerns.

The future of REs appears contested and political. Recycling initiatives are difficult and substituting them with other elements, if even possible, might just move the problems elsewhere or create new ones. Klinger (2017b) offers three ways to a more sustainable RE production: 1) Research should be taken seriously and claims made by the industry should be critically reviewed. 2) Certifications, tax incentives, and monitoring should push the market towards a more sustainable production. 3) Recycling initiatives should be strengthened in order to limit further extraction. To this I would add a fourth consideration: *decreasing* the demand for RE. Instead of creating an agricultural sector reliant on REs for efficient technology, other solutions should be seriously considered.

Steps toward this could include addressing the consequences of technology on political and public levels. Demystifying the socio-environmental relations underlying digital machines in the political debate could lead to political initiatives that could propose other strategies for the agricultural sector. Legislative demands of machine 'ingredient'-lists could provide supply chain transparency. Certification schemes, akin to e.g. the well-known 'fairtrade', could enable companies and end-users to choose RE-free or more sustainable technology. Finally, although quite the endeavor, our instrumental and reductionist perception of nature as well as the growth imperative in both the national economy and the agricultural sector should be revised. This would reverberate through both the world system of production as well as the Danish agriculture sector. This would decrease the tendency to ignorantly and hastily believe in the promises of sustainable growth offered by enchanting technological progress.

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Appendices

Appendix 1

Draft of initial mail – each was modified to the recepient:

Hej **xxxx**

Jeg hedder Niklas Jørgensen og er specialestuderende på Lunds Universitet, hvor jeg undersøger moderne landbrugsteknologi i en dansk kontekst. I forbindelse med det var jeg deltager til **konferencen 'Præcisionslandbrug: Kan teknologi erstatte miljøkrav?'/ AgTech-dag på Axelborg** for noget tid siden, hvor **du/I** deltog. Der er utroligt mange innovative og spændende tiltag på området, må man sige.

I forbindelse med mit speciale har jeg et par spørgsmål til jeres teknologiske løsninger, jeg håber **du/I** vil hjælpe mig med at svare på.

Jeg er interesseret i den fysiske teknologi, hardwaren, der anvendes i præcisionslandbrug og andre teknologiske tiltag. Med fysisk menes der apparater, sensorer, elektronik, computere, robotter etc. og altså ikke software til databehandling.

Jeg er derfor meget interesseret i at vide, hvor danske tech-virksomheder, såsom **XXX**, får den hardware, der er del af en given teknologi fra. Dette kan være med til at belyse de produktionsmønstre, der findes for moderne landbrugsteknologi og de muligheder og begrænsninger, der måtte være nu og for fremtiden.

Jeg vil derfor gerne høre:

Fra hvilke producenter/geografiske områder kommer hardwaren, der anvendes i jeres løsninger?

Er hardwaren produceret af jer selv?
I så fald; hvilke virksomheder/lande kommer komponenterne fra?

Elektronik har ofte en lang tilblivelsesproces med mange forskellige producenter og forhandlere bag sig – hvor meget af den såkaldte 'supply chain' har i kendskab til hos **XXX**?
Hvor højt prioriterer I at kende den/dele af den?

Hvilke overvejelser har I gjort jer omkring bæredygtighed ift. produktion og genbrug af hardware såsom førnævnte, der indgår i jeres løsninger?

Jeg håber meget at **du/I** vil tage **dig/jer** tid til at hjælpe mig på vej til endnu bedre at forstå den ny-ankomne og fremtidige landbrugsteknologi.

På forhånd tusind tak!

Draft of second mail sent out approximately 15 days after initial e-mail – each was modified to the recipient:

Hej,

Mon i har modtaget min mail? :) Jeg håber i vil tage jer tid at svare.

I mellemtiden er jeg kommet i tanke om et enkelt spørgsmål til:

Har i kendskab til om der indgår der sjældne jordarter/rare earth elements i de løsninger i laver? Enten i komponenter fra andre producenter eller i egen produktion? I hvilken grad anvendes de?

På forhånd tak

Appendix 2

Source: Private screenshot.

Appendix 3

Source: http://www.bbc.com/future/story/20150402-the-worst-place-on-earth. Credit: Liam Young/Unknown Fields.

Appendix 4

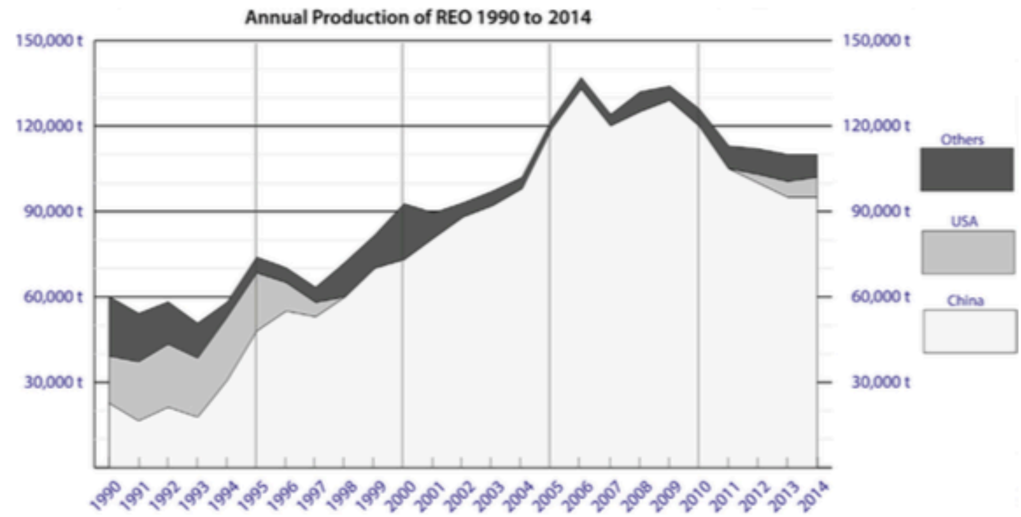

FIGURE 1

Rare earth element production, 1950–2014. Notes: The production data refer to the lanthanides, i.e., excluding yttrium and scandium production. Data given in metric tons (1 t = 1000 kg).

Sources: USGS Minerals Yearbooks 1994–2012; USGS Mineral Commodity Summarises 2015.

Source: Filho 2016, 7.

Appendix 5

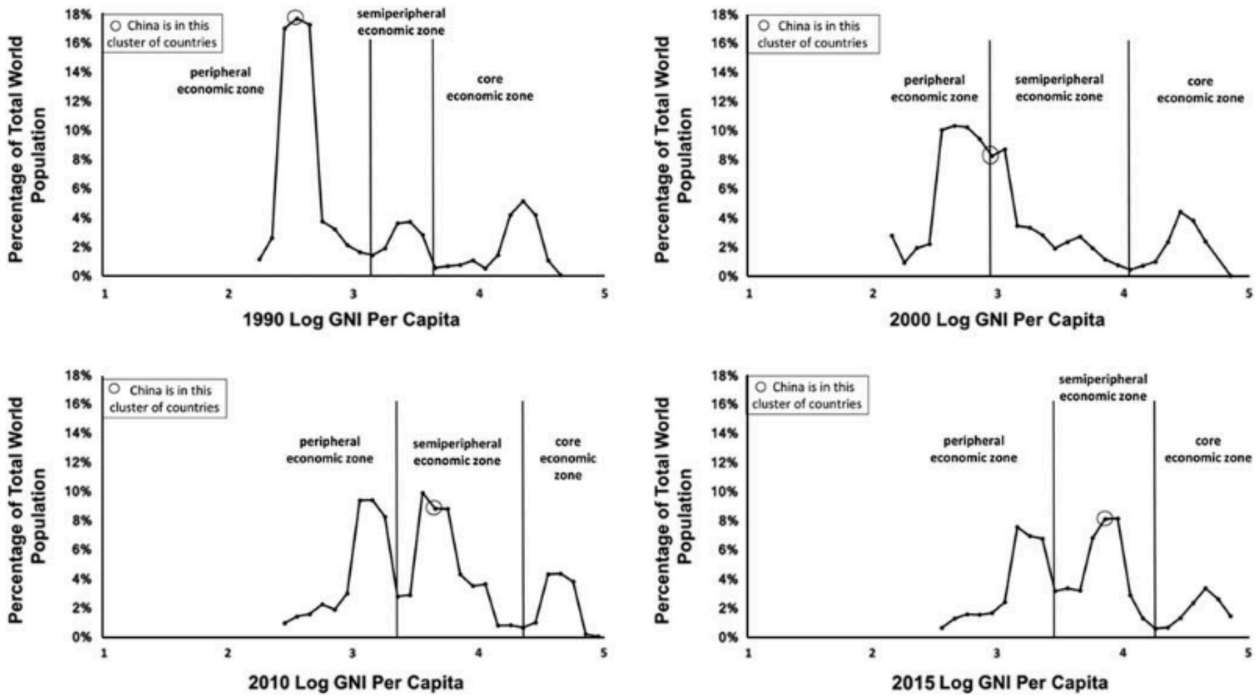

Figure 1 | Cut-off points for economic zones for the years 1990, 2000, 2010 and 2015.

Source: Grell-Brisk 2017, 5.