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Shopping for Heat From the Local Supermarket?

How the Transition to a CO2 Coolant in Supermarkets Could Change the Way We Heat Our Homes

Master's thesis in Globalization and Sustainable Development

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Abstract

The supermarket industry is going through a socio-technical regime change just as potent as the one the automotive industry is going through as it transitions to the all-electric vehicles. The goal for both is the same: a significantly reduced CO_2 footprint. The radical innovation for the supermarket industry is the use of CO_2 as refrigerant in heat pumps. The change itself is demanded by the fact that classical refrigerants are extremely damaging to the ozone layer. However, using CO_2 as a refrigerant requires a much higher energy expenditure and making up for it involves a complete restructuring of the supermarket and of its surrounding environment, including nearby buildings. In the case of the most radical innovation strategy implementation the supermarket needs to be designed and created from the ground up with the single intent of offsetting the use of a CO_2 powered heat pump and of using the resulting heat output.

The current master thesis follows the process of upgrading to the new technologies from the perspective of several supermarket chains in Norway, REMA 1000, KIWI, Meny, Asko, Coop. The first 2 pursue a radical approach to innovation while the latter 3 follow a more measured, incremental approach. However, together they create an ideal niche in which the new innovations have a chance to develop. The process is still in its infancy which means there are both drivers and barriers to innovation that need to be identified. There are landscape factors that encourage the attitudes of both supermarket chains, and the way they shape their response will undoubtedly determine both if and how fast the new innovations take root and are established as the new socio-technical regimes.

Contents

Nomenclature

CO_2	Carbon dioxide
HFCs	Hydrofluorocarbons
NTNU	Norwegian University of Science and Technology
Ppm	Parts per million
USA	United States of America
SNM	Strategic niche management

1. Introduction

Although not as glamorous or obvious as the transition the car industry is going through today, the supermarket industry is also faced with the necessity to align itself to the global requirement of minimizing its own environmental impact. There are several areas where a supermarket's carbon footprint needs to be improved, but the one that has triggered almost every other aspect of the change is the reliance on hydroclorocarbons HFCs(Manescu, et al., 2017).

Supermarkets rely heavily on the use of freezers and refrigerators, and for decades that meant using HFCs as refrigerants. HFCs are not necessarily contributing to the carbon footprint of the store, in fact there is a good argument to be made about the fact that they lessen that footprint, but they are extremely damaging to the ozone layer. For that reason, supermarket refrigeration systems have been slowly transitioning to alternatives, mainly systems using CO_2 as a refrigerant. These newer systems are a lot safer for the ozone layer, meaning the minor leakages that are bound to happen have no effect on it, but they require a lot more power and they put out a lot more residual heat. The way the stores deal with the implementation of these new innovations - from the extra costs acquired, to the extra energy output generated by the system, to handling the system's maintenance requirements - is the main focus on this paper.

In particular, we are going to look at the Norwegian supermarket chains, Kiwi, REMA 1000, Meny, Coop, and their main storage provider, Asko. They have been involved in the transition to the new technology, but they are using different approaches and market philosophies. While Kiwi, Meny and Coop rely on trusted, established vendors that have strong presence on the industrial level refrigeration market, REMA 1000 and Asko focus most of their energies on partnerships with cutting edge scientific research, implementing a lot of experimental protocols. Interestingly enough, both approaches have similar backers and the end goal is likewise similar in both cases although there are some significant differences. These are going to be described and analyzed through the theoretical framing of sustainability transitions.

1.1 Background and Motivation

A recent report released by the Trump administration warns of dire consequences to the USA and, implicitly, the world due to climate change. The warnings speak of an expected 4 degrees Celsius increase in average temperatures by the end of the century, and of the death of the coral reefs in Hawaii and the Pacific due to bleaching. The report also acknowledges an increase of

1 degree Celsius in average temperatures since 100 years ago, and a rise in sea water levels of 22 centimeters for the corresponding period. However, the report concludes that due to the accelerated increase rate of average temperatures, the trend is only marginally affected by the effects of several Obama era regulations, and therefore the Trump administration deregulations have an overall positive effect due to their influence on the USA economy (Transportation, 2018).

However, the same report admits to the fact that, without active regulatory intervention, the carbon dioxide concentration in the atmosphere would rise from 410 parts per million to 789 ppm (Transportation, 2018). That part of the report closely echoes the findings of the Second State of the Carbon Cycle Report in which carbon emissions in North America were down from 24 percent in 2004 to 17 percent in 2013 of the overall carbon emissions in the world for their respective years (Cavallaro, 2018). The new report credits the Obama era regulations, an increased focus on sustainable technologies, and the transition to a carbon footprint aware society.

The conclusion that can be drawn from the two reports is clear: both agree that climate change is a serious problem that future economies will have to contend with. Where they differ is in that the Environmental Impact Statement by the US Department of Transportation seeks to relax fuel efficiency standards, contending that the repercussions would be minimal at this moment. On the other hand, the Second State of the Carbon Cycle Report talks about the significant impact the regulations have had on carbon emissions as well as the fact that the economy increased due to new jobs and business opportunities being created in the sustainability industries. Both reports were drafted by bona fide scientific entities yet one sees economic success in deregulating the auto industry, while the other one sees it in doing the exact opposite: implementing further regulations and encouraging new sustainable technologies. The issue here is similar to the Hindu philosophy that the myriad of existing gods and philosophies are all different paths up a mountain but they all reach the summit, meaning in that context the ultimate reality. Similarly, it appears that different scientists and policy makers are looking and describing the same mountain but from completely different perspectives. In this case, the mountain is the ever-increasing effect human industries have had on the environment, and the paths are the almost diametrically opposed. And yet, we, as a humanity, seem to be committed to tackle this mountain and it would seem that the path that will be chosen has less to do with policies, although they are extremely important, than it has to do with the reasons large groups of people, industry experts and actors from all walks of life have.

The internal combustion engine has been and continues to be one of the major driving forces in the automotive industries and in the myriad other industries that are supported by it. However, the alternative sustainable technology ecosystem is slowly replacing every area that could not have existed without fossil fuels. The obvious example is the automotive industry where more and more car manufacturers from Nissan to Volkswagen, Audi and Jaguar are coming up with long-range capable electric vehicles. And there are also alternatives being proposed to replace the dependence on fossil fuels by making the switch to solar cell roofs, huge wind farms, offshore wind farms, and hydropower generated electricity.

Considering all of the above, it would seem that technological and even societal progress has less to do with the whims of the ever-changing governmental system, and more with a complex system of factors, motivations and sometimes and for short periods of time with the influence of what could be seen as smaller versions of the "great man of history". The concept of the great man of history is significant here, because, although it has been abandoned as a historical concept, it postulated that ever so often certain man would be destined to come on the historical scene to create change in an area that had become stagnant. The classical example is that of Alexander the Great whose conquests in Asia, although bloody and destructive, came just at the right time to open a path of communication and commerce between Europe and Asia (Carlin, 2013). In this context, I would argue that Elon Musk has more to do with the change to sustainable technologies than Barack Obama or Donald Trump. It has been noted that the character of the US politics changes drastically from one presidency to the next and therefore it is close to impossible to enact lasting change. However, as even the quickest glance of the history of Christianity will show, evolution, in the positive sense of the world, is possible. Not even the most devoted Christian today, will consider burning a witch at the stake, for example.

I mention the history of Christianity because it is the USA that votes almost consistently republican and therefore can be seen as conservative on any number of topics including the transition from fossil fuels. For now, "the good old boys" are still enamored with their V8 engines, but the Tesla Model S with its Ludicrous Mode is starting to make converts even on the racing scene. It is also among the conservative voters that the relatively new fad of survivalists is creating converts to the use of solar panels. Survivalists believe that the end of the government-imposed security and tranquility will soon come to an end. They believe that a natural or manmade calamity will, at any point, bring the destruction of the electrical grid and, with it, all the security and comforts of modern homes. They therefore are building their own alternatives using small solar panels, hydro powered generators, and even wind turbines.

My motivation for pursuing the question of how the transition from fossil fuels to sustainable technologies can be made, came therefore when I started to realize that people from both sides of the aisle are converging towards making the change, thus we see that a number of incumbents are starting to move into a more sustainable development position. Some may be actively fighting to preserve the old technologies, but even they are willing on occasion to embrace the new sustainable technologies. Understating the ways in which new sustainable technologies become mainstream is therefore a fascinating process and can help make the transition faster and more efficient regardless of the political administration’s views.

1.2 Research Objectives

The objective of this paper is to analyze the emergence of a new type of technology in refrigeration that I would argue, is emerging as a radical innovation. The technology is question is one that makes the switch from hydroflorocarbons being used as refrigerants to CO2. Since the change itself is just that of a certain fluid with another type of fluid, it may be argued that the change itself is just one that refers to an incremental innovation.

However, the use of a CO2 based refrigeration technology has several characteristics that put it in the overall niche category. One of the most striking characteristics is that of a “hopeful monstrosity” (Mokyr, 1990). That is because the use of CO2 as a refrigerant is immensely expensive, when compared with a traditional hydroflorocarbon, it requires the use a technology that needed to be developed just for its use, and that technology is still being refined and improved.

Currently, the use of CO2 as a refrigerant on its own, is still not financially feasible for any country or region below the 61 parallel. That is to say, it can only be used in the coldest parts of the world because the excess heat produced by the system can be further used only there. There are alternative systems that would use CO2 in a more economical manner, but those technologies are being developed at NTNU, in Norway, with the financial support of the government, and are slowly being rolled out in the Norwegian supermarkets by different actors who have, more or less, a free hand to experiment with the technology and to come up with their own ways of implementing it.

Thus we see 2 more characteristics of a radical innovation: the fact that it is developed in an artificially generated niche where it is allowed space for the learning processes, learning by doing, learning by using, and learning by interacting (Rosenberg, 1976; Von Hippel, 1988; Lundvall, 1988) to morph it into something that may break through the existing technological regime and to became part of the technological landscape. The other characteristic that differentiates the CO2 refrigerant technology from being a simple incremental innovation is the fact that it needs to be protected and insulated from the normal market selection processes.

For now, there is one final characteristic that needs to be taken into account and that is the disruptive potential of the technology. Unlike an incremental innovation, the use of CO2 as refrigerant has the potential of changing the entire sociotechnical landscape. The idea will be further detailed throughout the paper, but, to put it succinctly, the use of CO2 as refrigerant may involve changes in the way large cooling facilities, like storing houses, factories and supermarkets are built and also where they are built. A medium sized supermarket may become the heating powerhouse for an entire neighborhood, just from the excess heat generated by its CO2 heat pump. A large cold storage facility may very well cover the heating needs of a small town. And, because the heat pumps used by these facilities are the latest expression of the heating and cooling technologies being currently developed, they are a more efficient and more ecological than the current technologies currently being employed by small homeowners. Even in homes using heat pumps, or air conditioning units, those units are using hydroflorocarbons and are thus detrimental to the ozone layer.

From a theoretical perspective the goal of this paper is to follow up on future research needs as determined by other scientific papers on sustainability transitions. That is because there are 4 lines of focus that need to be addressed at a general level. The first one has to do with the need to further develop the conceptual framework. The four perspectives that are currently used as the bedrock of sustainability transitions research, and which will be described further along in this paper, are seen by some researchers as complementary, while others see them more as competing theories (Geels, 2011). However, there is a strong need for more than just refinement of the existing theories. There is a push for incorporating new concepts from related sciences and the need to use those concepts to better refine the existing methodological underpinnings (Jochen Markarda, 2012). While the overall goal of introducing new theories and expanding the methodological concepts of the field lies way beyond the scope of this paper, one of the objectives is to add to the discussion on what a niche technology is, and whether that definition can or should be changed to allow a more inclusive discussion of existing technologies.

The second need raised in this field is for a better understanding of the policy and politics of sustainable transitions. While my personal motivations for writing this paper have to do with the need to go beyond politics in an attempt to discover the means through which the progress towards sustainable transitions can be made without the need for political support, the fact remains that those resources need to be explored before they can be set aside. Early research in the field actually set aside the question of policy (Lovell, 2007) (Meadowcroft, 2009) (Scrase Ivan, 2009), which has left the questions relating to this side of the research open for further exploration (Flor, 2011). These questions have to deal with issues of where the power resides in specific sustainability transitions, how is that power applied and through which agency, what voices remain unheard, and what is the difference between a legitimate and an illegitimate transition (Jochen Markarda, 2012). I would say these, more than any other are the questions that this paper has (had) to deal with.

Lastly, the goal of this research is to help further clarify the geographical dimension of emerging transition processes (Lars Coenen, 2012). The debate between the concepts of regime and niche is one of the questions that has been addressed in this paper, and one that will be further developed through research. The question needs to be addressed within the geographical areas in which it emerges and therefore it is strictly connected with the research technologies that were under scrutiny.

2. Thesis Structure

The paper deals with two areas of sustainability technologies that are currently being developed and refined in Norway. The first one has to do with the transition from hydrofluorocarbons or HFCs, to the more environmentally friendly refrigerants such as CO_2 or hydrocarbons, in supermarkets. In particular, the paper will analyze the strategies made by the largest supermarket chains in Norway, REMA 1000, KIWI, Meny, Coop, and ASKO, the storage facility that handles the storage and transportation needs of the aforementioned supermarkets. The process involves more than a simple change, because CO_2 makes the cooling process much more expensive if it is simply inserted in place of the current HFCs, while the other nonpolluting hydrocarbons represent an ever-present danger of explosion. Therefore, the process of making the transition from HFCs to CO_2 or to hydrocarbons has to deal with all the actors normally involved in a system innovation from new technologies that need to be developed, to public opinion being swayed to embrace the new technologies.

The second transition that has been analyzed as part of the current paper has to do with a new approach to wood being used as a building material. Although wood used to be the main building material in Scandinavian constructions, concrete, steel and by-products of the oil industry have become the main staple to be used in large building construction, in particular large sports arenas that need a strong and yet small profile outer structure capable of transferring the weight from the roof down to the ground only through the sides of the building, especially in the industrial and big residential areas. The reason for that regime change were fairly easy to distinguish since the newer materials were easier to work with, longer lasting and could afford the construction of much larger buildings. However, due to new technologies being introduced there are several manufacturers and building engineers that are coming back to wood as the superior alternative.

These two lines of research, although seemingly different, are actually complementary. Given that the ultimate goal of supermarket chains is to develop a smaller carbon footprint, they actually need to do more than just make the switch to CO_2. In fact, the first challenge of using CO_2 as a refrigerant is that it requires a lot more energy to work. So, while the paper is structured in 2 major sections, one discussing the transition to new CO_2 heat pumps with all the auxiliary technologies that come with it, and the second part discussing the breakthroughs in wood building technology, the end result will be to see how both of these changes in technologies are being implemented in the new stores.

There is also a second dichotomy that the paper tries to capture and that is in the attitude of the supermarket chains and their approach to the implementation of these new technologies. KIWI, Meny, Coop, and ASKO rely on established manufacturers of CO_2 heat pumps and wood working professionals in order to implement the new technologies in a steady, reliable fashion across their entire chain of stores and storage areas. REMA 1000 on the other hand has invested heavily in research, developing its own internal team of researchers as well as funding a parallel team at NTNU. They are basing their entire strategy on developing the most efficient heat pump architecture possible. The radical innovation may be in this case the CO_2 heat pump, but they are already making incremental improvements, even going as far as bringing into the equation one of the oldest types of refrigerant that is still in use today, ammonia. The paper will therefore seek to follow how these different companies, acting as individual technological niches for the

CO2 heat pump development, have chosen to implement almost the same technologies only using completely different approaches.

Where KIWI, ASKO, Coop are, trying to minimize its carbon footprint by getting the most out of their heat pumps and further minimizing their effect by focusing their attention on wood as an alternative building material, REMA 1000 is trying to squeeze the most out of the refrigeration technology being employed. Both views are reflected in the paper and analyzed in turn. The paper tries to observe and analyze these attitudes through the prism of the theories on sustainable technologies.

It is for that reason that, after the preliminary and necessary introduction on the “Theoretical Background” and the “Research Design”, the following chapters will talk about the existing socio-technical regime in chapter 7.1 and 8.1, the new technologies being developed, chapters 7.2 and 8.2, the actors and institutions supporting the niche technologies and their reasons for doing it, as well as the areas where the system has failed to mass market the new concepts, chapters 7.3 and 8.3. Each of the two technologies will go through this type of analysis and each one will end with a look at the alternatives to the existing niche technology. The discussion here will debate both the merits of the technology being left behind as well as the potential of alternative technologies that are not being considered. The entire paper will end with considerations about future research and the conclusions that can be drawn based on the research conducted so far.

3. Theoretical Background

As mentioned before, there are four framings through which the process of sustainability transitions can be viewed through. Their description represents the bulk of this chapter, however there is a stylistic choice that needs to be defended first. Traditional approaches to discussions about the theoretical framework of socio-technical regime changes rely on a small number of examples like the change from DVD systems to Blueray, or discussion on the emergence of electric vehicles. While all of these examples are pertinent, a more interesting approach, due to the fact that it is not one usually being considered, is the emergence of the Uruk-hai as the ultimate worrier in The Lord of the Rings. For simplicity, the Uruks discussed here are considered as they appear in the first movie in the trilogy, The Fellowship of the Ring, where Saruman, their creator, describes them as:

“They were Elves once, taken by the dark powers, tortured and mutilated. A ruined and terrible form of life. And now, perfected. My fighting Uruk-hai”

Before approaching the main interpretation of the different points of view regarding sustainability transitions, there are two important concepts that need to be introduced first: that of a niche technology and of socio-technical regime.

3.1 Socio-Technical Regimes and Niche Technologies

The concept of socio-technical regime has its birthplace at the confluence of evolutionary economics (Nelsonand Winter 1982) and the sociology of history (Wiebe, 1987). It begins with the idea that scientific knowledge and the ways in which it is being used, is also embedded in the social practices of the day. Taking a look at the Lord of the Rings example, as the story begins, the war technology that the dark forces of that world use are the orcs and the trolls. They are often referred to as mindless both by Saruman and Gandalf, and they tend to be easily controlled by a greater power like wizards or embodied spirits called Maia. They are extremely aggressive in battle and useful from that point of view but cannot fight or even march during the day. Orcs are slow and usually do not travel when the sun is out, and trolls actually turn to stone if touched by the sun’s rays. Therefore, the entire society is built around the concept that the day is safe and the night or the dark places of the world are where dangers lie. Therefore, the concept of a socio-technical regime needs to be established as clearly more than a specific piece of technology, but also how the society using that technology exists and defines its own reality based on the incorporation of that technology.

In this context, a niche is defined as a safe harbor in which a new technology can be developed and tried out without it having to deal with the competing technology. The problem with an existing socio-technical regime is that the society at large is already so compliant with a certain way of doing and understanding things that it would not even consider the use of a completely new technology. They may accept incremental changes, but not a radical new approach (Geels, 2006). To follow up with the original example, it was Saruman, the head of the wizard council, that first developed the fighting Uruk-hai. He describes them as elves that have been tormented and warped to become the new weapon, one that can fight and march just as well in sunlight as in the dark. They are first deployed when Saruman sends them to retrieve the hobbits carrying the one ring of power. There is a clear separating between them and the other orcs as they chase the fellowship of the ring, but they establish themselves as dominant over the orcs. For days, Aragon, the leader of the party being followed by the Uruk-hai, is not aware of the fact that they are being followed by a force able to chase them both during the night and during day light. Ultimately, the Uruk-hai manage to trap the hobbits, although not the right ones, and end up also killing the party of orcs that was traveling with them. However, even though they clearly prove their superiority it takes another 2 movies until we see Sauron, the ultimate evil in the movie, finally starting to breed Uruk-hai of his own, although the majority of his army is still made up of orcs. His original attempt to create a newer, stronger army is actually a perfect example of an existing socio-technical regime trying to perpetuate its existing technologies only by improving them. In several scenes in the movie it is suggested that Sauron is mixing orcs with goblin men trying to create an army that would be able to fight during the day. The point here is that both the humans, dwarfs and elves running from the Uruk-hai, and Sauron himself, are not able to fully grasp and accept the new technology as a part of their world. The reason why the analogy to regime theory makes sense here is that the innovation system, the Uruk-hai, represent a complete breakoff from the traditional way of doing things. All of the characters involved, except for the developer of course, require time and experience to adapt to the new war technology they are chasing and fighting. (Geels, Raven 2006)

3.2 Theoretical Framing of Sustainability Transitions

The importance of socio-technical regime changes came to the forefront with the development of sustainable technologies. Therefore, the study of sustainability transitions, the process through which socio-technical regimes could be influenced to adopt sustainable technologies, came under scrutiny. One of the first attempts grew out of the need to study how niches grow and develop. It is called Strategic niche management (SNM) and it focuses on the purposeful creation and support of this type of niches, that would encourage a regime change towards sustainable technologies (Geels, 2006) (Raven, 2006). Here the focus lies on the creation of a safe niche where new technology development can take place. In our running example, we see Sauron order the orcs to destroy the forests around his forest, Isengard, and to create the underground ditches and wells in which Uruk-hai can be created. As they are formed, their first attacks focus on the very goblins that created their environment.

A second perspective on sustainability transitions is that of the Multi-Level Perspective. Here a transition is seen as the interplay between niches, regimes and landscape (Geels, 2002). The concept of the landscape has to do with the overarching tradition of a specific area, its values and vision regarding the different aspects of life, that can be furthered leveraged in the creating and promotion of a niche technology that can be seen as part of the “landscape”, and therefore it is much easier to be accepted by the socio-technical regime. From this perspective, Saruman's role as a chaos agent, dealing both with the elves as their friend, but also under the sway of Sauron, can be seen as developing as a character in the perfect landscape. His deep understanding of elf lore places him in the correct frame where he can conceive of the elf as the ultimate warrior. And his slow change of allegiance from the Elf Council to Saruman's aid, is what introduces a series of gradual innovations in the world of Isengard, from where he rules. Examples of this slow change can be heard in Treebeard's complaint that Sauron is no longer taking council from the ents, that the villagers surrounding Isengard have a mind of "meta and steal", and it can also be seen in the emergence of goblins as aids of Sauron instead of ents and elves. On the other hand, it could be argued that since Saruman had been fighting the elves for so many eons, he did not have the required tradition, landscape, in which the concept of turning the elf into an Uruk-hai could naturally occur or be encouraged.

The third line of research is known as active interventions and transition management. Here, the focus is on existing transitions and on the way of influencing them to take a more sustainable path. From this point of view, transition management sees existing sectors of industry as complex social systems and the process of influencing them is one of perpetual evolution alongside them. (Geels, 2006) The prescription from the transition management research is to conceptualize a specific area as dominated by multiple stake holders among which coalitions can be encouraged, experiments can be conducted to encourage development down a path versus another, all the while monitoring the process and being willing to switch tactics accordingly.

Saruman plays the role of the government in the Lord of the Rings and the way he encourages the adoption of the Uruk-hai as the mainstream weapon or warrior is by sending out small parties where Uruks orcs and goblins fight together. He then sends an entire army of mostly Uruk-hai in the final battle of the second movie in the trilogy against the fortress at Helm's Deep. Ultimately, they are defeated but not before breaching and almost completely overtaking a fortress that had been deemed as impossible to conquer while it was defended by men. In that fight, a contingent of elves also ally themselves with the men defending the fortress and they are more or less defeated. So, from the point of view of a governance system trying to manage the transition to the new tech through an active intervention, Saruman is a complete success. By ultimately losing the battle he is removed from the scene but we see his ally, Sauron taking up the Uruk-hai as his elite warriors.

3.3 Technological Innovation Systems

The fourth and final line of research into sustainability transitions has to do with a bottom's up approach called Technological Innovation Systems. It is the more complex of the four which is why it has its own sub-chapter and will actually form the basis for the analysis of the current existing technologies. The concept was created by Carlsson and Stankiewicz in their paper "On the nature, function and composition of technological systems"(Carlsson and Stankiewicz, 1991). Their analysis showed how the interaction of firms and other actors constrained by a specific system is essential in the development and promotion of new technologies. That initial theory was then further developed by the identification of key processes that need to run smoothly in order for the system to work well. That drove the research towards radical innovations that had the best chance of radically affecting the socio-technical regime. Therefore, the system now focuses on the drivers and barriers to innovation, seeking to find system failures when analyzing the permeability of the market to a specific technology.

The analysis here focuses on so many systems and their interaction that the Lord of the Rings analogy tends to break down. However, there are a few concepts that can still be applied. For one, the creation and implementation of the Uruk-hai now needs to be considered from multiple points of view. One significant question is just how many elves can be captured alive at one point so as to be tortured and tormented in order to be transformed into Uruk-hai. Presumably the process was started several years before the war of the rings, but once Saruman's main army was destroyed who could, on short notice, capture new elves to torment, and, more important at what cost. Sauron manages to do that but he had to consider the cost in orcs he has to pay for every elf captured. We are never told how he manages this, but since he is building his army on the remains of his former citadel that had been destroyed eons before during the War of the Ring, it could be argued that he had elves trapped there since then. He also needs to consider how the new Uruk-hai would be implemented in his armies which have a much more complex composition than Saruman's armies. Finally, he needs to consider that he is already waging war so he does not have the luxury to demonstrate the superiority of the Urucs to his armies and, more important, his Nazgul generals.

4. Research Design

The research is based on a multiple case study of the biggest supermarket chains in Norway, REMA 1000, KIWI, Meny, Coop, ASKO. They are all focused on decreasing their carbon footprint and have by CO_2 as the main refrigerant. However, they are completely different in the way they approach the implementation of their CO_2 heat pumps and all the auxiliary innovations that make the transition possible. This difference in approach gives the opportunity for a comparative analysis of several cases studies of the way an innovation niche is being created in the supermarket refrigeration system and how it then expands.

As will become evident, KIWI, Meny, Coop and ASKO uses dedicated, global vendors like Danfoss to implement the most basic and reliable version of CO_2 heat pumps on the market. Wherever possible, they rely on experienced providers and rely on niche developers only in the support areas where they have no other choice, like the solar panels that provide the extra energy required by the new heat pump, and they rely on new wood processing technologies that allow for the construction of large halls like the ones needed for supermarkets, and thus they use the store itself as a C02 trap and also use less concrete and cement in the construction. Their focus is on testing out the technology and rolling it out to the entire chain of stores as quickly as possible. REMA 1000 on the other hand, has made a single foie in implementing the latest CO_2 heat pump design and auxiliary technologies in their latest store in Trondheim, Kroppanmarka. They worked with an entire NTNU research team, developed their own, in house research team and relied on Danfoss only for the basic hardware. Based on that experiment, they continued and expanded their experiments, working with the NTNU team to develop a more advanced cooling system for a chicken processing plant that is to be opened in Orkdal. The new system will use a CO_2 heat pump in tandem with an ammonia heat pump, and a cold storage unit.

The difference in approaches makes for a potentially interesting study as it gives one the opportunity to see the development of new niche technologies and their implementation in real time. The informants are all deeply involved at different stages of the process from research to implementation and monitoring, so they are perfectly positioned to provide information about both the drivers and the barriers to innovation in this field.

For the research, I choose to use a semi structured interview. Of the three types of interview, structured, semi structured and unstructured (Lain, 2016) I decided to use the semi-structured interview. The reason behind this choice had to do with the type of research I was about to conduct. My main questions needed to find the reasons behind the apparent choices my informants had made when choosing a particular technology to focus on. That meant a certain give and take would have to occur where I would be training the informants on the goals of my research while we would be discussing their area of expertise. Thus, the ultimate question of what are the power structures, motivations and actors that are promoting the use of sustainable technologies in Norway, would only be posed once we could arrive at a common consensus of what those technologies were. As a starting point, I knew I could base my research on the basic understanding of the current state of the technology as it is presented in current newspapers. However, many of my sources were several years old, so I expected that some of the technology being discussed, as well as the promoters and early adopters of that technology would have changed in the interim. I was actually proven correct on those assumption, so the use of a semi structured interview proved to be the correct choice.

5. Methodology

In terms of the method of choosing my informants, I decided to focus on the people developing, implementing and using sustainable technologies in the supermarket refrigeration industry as well as the building industry.

More precisely, the interviews have focused on 4 researchers from NTNU, 4 system administrators from the 4 largest supermarket chains in Norway, KIWI, Meny, Rema 1000, Coop, the system administrator from ASKO, the company handling the warehousing and transportation of food products for Coop and some of the other major supermarkets, a system engineer for Statkraft, a state owned company that, for the purposes of this paper, handles the heating needs of different residential areas, and, finally, a system administrator from IKEA Leangen. While the initial project was focused on just two supermarkets, Kiwi and Rema 1000, through the course of the interviews, as well as during the process of writing the master thesis, opportunities presented themselves for more interviews. The interview with Kiwi actually created a snowballing effect where more and more doors opened and different research avenues presented themselves, and they led to the ASKO interview, which turned out to be the gateway to an avalanche of opportunities both in terms of further interviews as well as avenues of research.

I have started the interviews with the PhD and a Post-Doc researchers from the Refrigeration Energy research group at NTNU, whom were involved in the implementation of the first complete heating and cooling system based on CO_2 in Norway, in the Rema 1000 Kroppanmarka, in Trondheim and who are continuing to develop newer and improved versions of the existing CO_2 based technology. Being so close the research itself, both informants have had a deep understanding of the technology being used, as well as the reasons for its implementation and have a good idea of the institutions and actors funding the research.

Following those two interviews, KIWI was the easiest to get in touch with and I was contacted by their country level system administrator. I conducted 2 interviews via phone that I recorded and subsequently deleted on a second phone. Of all the interviewees he was the most open to keep the conversation going. That meant that, although I followed the interview guide, we went off on tangents about other technologies that I did not know about, as well as his insights on the policies and motivations of other competing companies, like REMA 1000. There seems to be a deep understanding of the level of research of each company at this level of specialization, although there is also somewhat of a friendly rivalry where each engineer seems to be trying to outperform the other one. The one particular important detail was that Vegar, the interviewee, was completely forthcoming about the himself and the information he was providing. Therefore I did not need to hide his identity. After the interview with him, all the other interviewees, when asked about the level of privacy they expected, just asked what Vegar had said and followed suit.

The next interview I managed to secure was with the system technician ASKO, Staale. It is important to note that I had tried to secure an interview with REMA 1000 for several months but did not succeed, and it was Staale who gave the right contact person and his phone number. Besides that, it was him that had the most comprehensive view of the state of technology and how it should be implemented. He was also one of the few interviewees with whom the Department of Energy and Process Engineering at NTNU is in close contact with, to allow their students access to a working, state of the art refrigeration system. Therefore, he was able to explain the state of the technology in much greater detail and more eloquently than the other interviewees. With Staale I was also able to conduct the last interview before the Corona virus pandemic became an issue in Norway, and therefore, I was able to have that interview at the ASKO headquarters. On this occasion I was able to see the heat pumps in action, the heat ports on the roof, the solar panels that ASKO is currently using, as well as the hydrogen facility that they are using.

The next interviews were over the phone with the system engineers from MENY, Rema 1000 and COOP and there. Because of time constrains and sometimes bad phone connections I restricted myself to the interview guide. As will become obvious in the rest of this paper, the interview with Erik, the system engineer from Meny was the most productive because it opened up an entire wing of investigation. In short, his approach is totally different than that used by NTNU and his credentials are on par to those from NTNU, so, although there are differences in approach on all these supermarkets, his is the one that creates major schism in the transitions to CO2 heat pumps.

Finally, I had a chance encounter with Kent, a former engineer that worked for Statkraft. This interview was of particular interest to me because a big part of my interview with Staale at ASKO had focused on the potential collaboration between the two industries. I will go on in greater detail later in the paper, but the most interesting point I had discussed with Staale was that Statkraft would be the perfect place where ASKO could send the extra heat generated by their systems. The reasons why that collaboration has not taken place were the focus of my conversation both with Staale and Kent. Furthermore Kent was able to give me a short city tour and to point out all the Statkraft plants and reheating plants, thus opening the avenue that more supermarkets could integrate their heat pumps with the heating system of the city.

The other interview were conducted with the project leader from Green Advisers AS, a company developing new building technologies using wood as the primary material. Although wood as a building material was one of the first products used in our history throughout the middle ages, it was largely abandoned with the advent of concrete, steel and by-products of the oil and gas industry. However, Green Advisers, together with other manufacturers in Norway are developing new technologies that are turning wood in a material that can rival concrete and steel as building materials in the large buildings area. In addition further interviews were conducted with the project leaders from REMA 1000, Meny, Asko, Coop, and KIWI in order to get their perspective on the decision process behind the implementation of the various types of sustainable technologies available on the market

From an ethical perspective, there is always the danger of over-representation (Iain, 2016), especially since some technologies are not patented or are not fully developed and therefore may not be covered by patents and thus, although this master thesis does not delve too deeply into the actual engineering mechanism, there is the chance that a simple hint or slipup from the interviewees could reveal more about the specific technology than it should be revealed.

However, since these are technologies where the basic functioning parameters are widely known in the scientific community and elsewhere, there is very little chance that the more sensitive parameters would even come under discussion. So, following the principle of informed consent, I have encouraged my informants to feel perfectly comfortable to stop the interview or to refuse to answer questions that they feel might contravene to their company's policies. The Green Advisors informant actually made full use of this provision and the potentially sensitive information provided by the NTNU informants is already a matter of public knowledge due to publicly available scientific journal articles. Their input though was of immense importance since they were able to convey the most essential information and were able to theorize on the social aspects relating to the mass acceptance of their respective technologies.

Although the strictest protocols of anonymity were part of the initial target of the research, it quickly became obvious that the identities of some of the interviewees would be almost impossible to fully conceal. In particular, even the slightest google search on the newer technologies regarding the use of wood as the main building material will reveal the identity of the Green Advisors informant. Equally, the quality of the information as well as the birds eye view of the process through which KIWI decides which technologies to invest in - why they choose those particular technologies and, more importantly, how they monitor the impact these technologies have on the business side as well as the CO_2 foot print side - are all bread crumbs that would easily lead any advised reader back to the real identity of the informant.

For that reason, I have contacted all of the 10 informants to express my concerns and to explain what I was planning to do if they were not happy with the current level of anonymity. For one, it seemed like an overreach, tempting as that might have been, to declare the entire paper confidential and to be used within NTNU only. The best option put forward was to cover in anonymity the names of the companies involved and thus hide the identity of the informants under a secondary layer of secrecy. However, all of the informants came back with different variants of the same answer. The most comprehensive version was that of the KIWI informant who said

"For Kiwi and me its nothing sensitive information that we do not want to share with anyone who are interested in what we are doing.

Be free to do what you think is best for your paper and the readers !"

Therefore, at this point the only point of clarification that needs to be made is that the pseudonyms for the NTNU informants are N1, who is PhD Researcher in the Refrigeration Department of Energy and Process Engineering, N2 who is a Post Doc in the same department and N3 is a Phd in the same department, the Green Advisors informant is G1, and KIWI, Meny, ASKO, Statkraft and Coop will be referred to by their first names as they did not ask for any special anonymity conditions.

The interviews were taped but I also wrote down the main points in every interview. For the analysis in this paper I focused mostly on the notes I took and referenced the tapes only where I could not remember a specific name or number. Both the notes and the recordings will be deleted once the paper is accepted and graded at NTNU.

Considering that the current paper relies on a multiple case study where the informants are the very people involved in the project of implementing CO_2 heat pumps, multiple interviews should reveal similar results. The very fact that, after the Meny interview, further information started to be repetitive would seem to indicate that, at supermarket level, the quantity of information seems to have been exhausted. However, the Ikea interview shows off one of the limitations of the study, as this is another giant warehouse that is still relying on standard heating elements and heat pumps. Thus further interviews with other representatives from other large buildings, perhaps ones that do not rely on the city grid for heating, would show that the level of knowledge about the CO2 heat pump and its usefulness has not yet permeated at all levels that can make use of it. The informants did speculate to some extent about the motives of investors or company owner and were bound by the level of technology that they are currently developing. As a result, future developments in the refrigeration technology may result slightly different answers, but all of the informants tend to agree on the fact that the innovation technology has already been found, and the next years will only see it go through incremental evolutions. Therefore, the current paper, in its analysis of the current niche technologies being used by supermarkets in Norway should be quite reliable and easily replicable.

In terms of the internal validity of the subject, I have tried to make the case that the CO2 heat pump represents much more than just a change of the coolant being used. The point of inspiration was Geels' 2002 analysis of the emergence of the steam ship, first as a radical innovation technology existing in its own safe niche, and then ultimately taking over the use of sail ships and redefining the entire concept of a ship. Similarly, the change to CO2 as the main coolant has the potential to change the way heat pumps and supermarkets are perceived in the community. It is thus not an incremental innovation but a radical one. Thus I have tried to draw a direct line between the existing integration of a supermarkets heat pump and its ability to provide heating for a nearby building, and a line of the future where supermarkets are integrated in local communities providing them with heat, all the while reducing their own carbon footprint. The interviews I have conducted certainly would indicate that the potential is there, but until it is actually implemented, the value of this innovation has yet to be proven. KIWI has already implemented a heat pump system that manages its cooling needs and that generates enough heat as a by-product to heat 3 neighboring flats. Based on that test, and several other similar concepts that have been implanted or could be implemented by the other supermarkets in Norway, we can speak of the CO2 heat pump as a radical innovation. However these test pilots have yet to be integrated in the heating grid of the country and, until that happens, the question of whether the CO2 heat pump truly represents a radical innovation or just an incremental one cannot be determined.

6. Analyzing Innovation Avenues

As things stand at the moment, there are two important challenges that supermarkets have to face: they need to keep the inside of the store at a temperature that is comfortable for the customer, but they also need to keep at least some of the goods that they deal in at temperatures below the freezing point. Usually, handling these two requirements has been a battle fought on two fronts, but the need to minimize their own carbon footprint has united the fronts. The problem with transitioning from systems that use hydroflorocarbons as refrigerants to systems relying on CO_2 is that the later generate massive amounts of heat. As the second law of thermodynamics tells us, that means there is a lot more energy being used by a CO_2 cooling system. In refrigeration parlance, it is often said that heat is extracted from the display cabinet or freezer by the coolant system, and that heat is then rejected to the ambient. That is the basic function of any type of refrigeration unit. The problem is that the functioning of a refrigeration unit that uses CO_2, pumps out more heat than one powered by HFCs, because the use of CO_2 itself requires more energy. As it will be seen below, the extra energy is being used then to heat up the store, the outside driveway so that ice does not build up in winter, and sometimes even as a heating source for the surrounding buildings. However, even under these conditions, sometimes there is still too much heat being produces which means the stores are still not running at optimal energy usage. (NTNU PhD, Trondheim, 2018, Personal Interview)

This is where the other side of the equation of maintaining a store comes into play. The actual design and built of the store create massive amounts of CO_2. For that reason, newer designs focus on 0 emission stores, meaning that they have such a good layer of heat insulation that they do not lose the heat generated inside. However, the traditional building materials that are usually used are also the source for a lot of CO_2 production. Using concrete as the main building material adds multiple layers of CO_2 into the atmosphere, starting with the manufacturing process but also when taking into consideration the distance concrete has to travel. It is for that reason that supermarkets are also focusing their attention on using the latest wood working technologies. Traditionally, it has not been possible to use wood as a main building material, however there are several innovations that are changing its functionality. Finally, and as we will see later on, wood may be an excellent alternative to the use of traditional insulation materials, which are by-products of the oil and gas industry and therefore adding to the carbon footprint of any building.

7. Heating and Cooling Technologies

The first area that I decided to focus on where there is a massive push for a transition to sustainable technologies is the heating and cooling aspect of running a supermarket. The main challenge here is that the standard, socio-technical regime accepted cooling fluid is some member of the hydrofluorocarbon's family HFCs, and it is one of the most damaging gasses to the ozone layer. However, it is essential for running not only the refrigeration system, but also the heating and cooling of the store.

7.1 Current Socio-Technical Regime

Modern stores and even most houses are warmed by a heat pump. The device itself can be used to pump heat both in and out of an environment, which means it can be used to both heat and warm up an environment. The standard technology being used to cool down fridges and freezers, to warm up in the winter or to cool down in the summer a store, home or car relies on individual heat pumps for each one of these different environments. That notion is crucial for many reasons in a discussion about the transition to alternative cooling fluids. The problem stems from the fact that HFCs are a by-product of the oil and gas industry and are, therefore, extremely cheap.

That meant that when the technology was developed, the goal was to keep it as simple and as basic as possible, relying on the standard philosophy of simple problem, simple answer. However, no system is completely sealed off from the elements, so HFC ran heat pumps have what could be called massive leakages, especially when compared with modern heat pumps. In fact, most industrial heat pumps require a specialist maintenance crew to inspect and fill them back up with HFCs every year. However, because the HFCs are so affordable, the end users do not care about the inconvenience, especially when considering how much more expensive a better sealed heat pump would cost according to my informants from NTNU.

Making matters worse is the fact that, in order to create heat pumps optimized for their task, a store contains multiple heat pumps. That is because the technical requirements for a heat pump that is supposed to keep the temperature in a freezer below -4 degrees Celsius, are completely different from those that a heat pump maintaining a comfortable ambient temperature in the store would require and are also different from those maintain the temperature in the freezers. Furthermore, due to the fact that these units would have to be moved from one area of the store to the other with ease, they would usually have each its own heat pump. So now, instead of having just one heat pump leaking HFCs through one or two of the joints making up the system, there are anywhere between 3 and 10 heat pumps, and each one is leaking to some extend or another.

The EU has been trying to limit the use of HFCs and to encourage the implementation of improved or different systems according to the NTNU informants. The main tool that they can use is to impose higher and higher taxes on the use of HFCs. So, what was once a very cheap to use refrigerant, is now and has been for some time, becoming more and more expensive. The solution is a little bit more nuanced though, because each of one the hydrofluorocarbons family members has a rating in terms of how damaging it is to the ozone layer. CO_2 has no impact on the ozone layer, which is why it is the golden standard with a rating of 1. Most HFC have ratings of 500 and beyond and are taxed according to that rating.

The EU regulations managed to achieve their goal because the industry producing HFCs has been forced to invest massively in research and development. Over the past 20 years, refrigerants with much more damaging potential were replaced by somewhat lesser damaging ones. So, the 500 rated refrigerants being used today are actually a massive improvement on the ones being used a few years ago, but the change is actually very recent. In fact, N1, one of the NTNU informants, was telling me that he had to take his car in to have its refrigerant changed because it was no longer properly cooling down the car in the summer, and that in all likelihood this would be the moment when his car would finally be rid of the last remnants of the more damaging refrigerant and come up to the modern standard. So even older heat pumps can be retrofitted and can use the newer coolants as long as they are from the HFC family.

Despite the increasing regulations and taxation that is trickling down to almost every aspect of the end user's lifestyle, the lobby for HFCs is still very powerful. When talking with both of my NTNU informants I asked them about the less altruistic motivations that might be behind the EU controls. They both answered that there are none that they can see precisely because the EU regulators are under tremendous pressure from the HFC manufacturers. They have had many years in which to build a strong financial stronghold and are using all their might against the ever-increasing regulations.

Interestingly enough, the HFC refrigerants can be seen as the incumbents in their traditional form, but also that of the alternative technology that is not being heard. The reason for that is that newer, more advanced HFCs have an ozone impact potential only a few steps above that of CO_2. That is because, while talking with N2, the second NTNU informant, I asked him what the most outlandish, even Jules Vernes-ian alternative to the current research avenues he is working on would be. His answer was that the HFC manufacturers were actually developing their own alternatives, some of which had an ozone depletion coefficient of close to 10 or below. Granted, that is still a much higher coefficient that CO_2, but the fact remains that, at the most basic level of the technology, carbon dioxide is much more expensive to use in terms of the heat pumps being used.

7.2 Innovation Niche

Research set up and its support within NTNU are one of the safest niches where the new technologies in refrigeration are given a chance to grow and develop. For various reasons that will be explored in the next few paragraphs, there is a consortium of economic powers that are investing massively in research, and in particular in NTNU. These are The Research Council of Norway, Industry Partners among which REMA 1000 features prominently, Norges Gruppen, Danfoss and SINTEF.

7.2.1 The Power Behind the Transition

As mentioned before there is one other great institutional influence in the question of refrigerants and that is the European Union. Their concern seems to be genuinely not based on short or even medium-term economic reasons. They are facing a massive backlash from the HFC refrigerants industry which they are trying to phase out. Current plans envision a complete phasing out of HFCs by 2030. Therefore, although they are not contributing directly to the research efforts conducted at NTNU or in Norway, by preparing and opening up the huge market potential of the entire European Union, they represent a strong encouragement for Norwegian potential investors to put their shoulder to the task of developing alternatives.

The Research Council of Norway is motivated too by ecological reasons just as much as the European Union, but they also have alternative arguments that motivate the investments they are willing to make. Accordingly, to N1, the costs of labor is much higher in Norway than anywhere else in Europe or Asia. However, due to living conditions in Norway, as well as the interaction between unions and the policy makers that make it impossible for the cost of laber to be driven down, the Research Council is interested in developing more energy efficient technologies than the industry competitors outside of Norway, thus developing cost savings on that front and making it possible for the price of products to stay low. They are also hoping to be able to keep as many jobs as possible in Norway, by providing manufacturers with more efficient technologies. N2 has a very similar opinion only he is more focused on the profit margin. In his view the CO_2 technology needs to be able to provide refrigeration that is more affordable than the one being used in Europe. Thus, the Norwegian commercial food producing and packaging companies will be able to get a larger profit margin by keeping their businesses in the country, rather the exporting parts of those processes abroad. Both informants agree that the ultimate goal has to do with keeping jobs in Norway and increasing the country's economic status.

The industry partners among which REMA 1000 figures prominently have an even more convoluted reason for investing in NTNU research. REMA 1000 and its partners act as a more or less disinterested investor because they are betting on the potential of the new research. N2 gave the simplest explanation when he said that "these industries cannot all use the technologies being developed. We might be working on more efficient refrigeration systems for REMA 1000 at the moment, but the technology developed here can be adapted down the line to be used in the oil and gas industry, and so on". N1 pointed to a second reason why the consortium is interested to invest in a large array of NTNU research projects: depending on their particular interests and on the sums being invested anyone of these companies can have a designated PhD or post-doc student focusing on their own needs. So, they are not only getting access to the latest technological developments, but they can have a dedicated researcher working on finding the best way of implementing those solutions in their own company's current development projects.

REMA 1000 in particular has a third benefit from their collaboration with NTNU because they have their own research team and they can leverage the efforts of that team as "in kind" contribution to the overall project. So, although there are projects in which they invest financially, they can also take part of research projects with their own team. In those cases, although they are required to have their own investment in order to get a seat at the table, they can actually bring in their research's team's efforts as an investment "in kind" rather than investing actual money. They can then reinvest that money into obtaining a dedicated PhD who will develop a product specific for their needs.

7.2.2 Innovations in the Heat Pump Technology

The current socio-technical regime relies on HFCs as the standard cooling fluid. In Norway, because of investments by the government that have started as early as 2012, the transition to CO2 as a cooling fluid is in full swing but not yet complete.

However, the transition to the new technological regime are faced differently by the different companies implementing them. In effect we can see several niche markets implementing the new technology and developing their own answers to these challenges. At Asko the challenge for the main engineer is to strike a balance between the energy used to generate cold energy and the pressure under which the system operates.

> A heat pump works by forcing a fluid to change phase from a gas to a liquid and back again by changing the pressure level in a condenser. When the fluid changes phase it either generates or releases heat and that principle is used in the heating and cooling industry. (NTNU PhD, Trondheim, 2018, Personal Interview)

The current heat pump used at Asko could generate enough heat for the entire surrounding neighborhood. However, heat is only a byproduct of the cooling energy that Asko requires and, therefore, taking the responsibility of becoming a heat provider is not something that Asko is currently interested in. They are further disincentivized by the fact that the higher pressure they would need to keep their systems under would only add wear and decrease the life expectancy of the heat pump.

However, as seen in the picture below, ASKO is currently forced to dump heat into the atmosphere. Their system is working at an average energy use level comparable to a heat pump using HFCs, but that is due to the fact that they can use some of the heat generated by the system to keep their parking lot free of ice during winter.

Figure 1

That means that the entire system could further be improved if the heat currently generated by the system would be used to heat some of the housing complexes close to ASKO. KIWI has already attempted that solution and, although successful from an energy balance standpoint, the administrative challenges of controlling two systems – the store and the residential complex – have generated enough issues to make the task daunting for most system administrators, according to the project administrator from ASKO. (ASKO System Administrator, Trondheim, 2019, Personal Interview)

There is a simple solution that, at least for the ASKO facility in Trondheim is within reach and that is the Statkraft heating facility located less than half a kilometer away. They have already the setup required for providing heating to the city of Trondheim and they are actively burning wasted from the neighboring trash dump. They could easily absorb the extra heat generated by

ASKO, and decrease their own heat generating efforts. In theory, because the heat pump is a more efficient heat generating system, ASKO could increase the pressure in their own systems, generate more heat, and cover more of the city's heating needs.

The very fact that this obvious pairing is not being explored is proof that, even in Norway, the CO2 heat pump is a niche technology that is still making its way into the existing technological regime. A full understanding of the potential of this technology, as well as a complete integration into the other heating and cooling systems of the country will is likely to come about as the new technology becomes more prevalent and its potential is better understood.

The challenges of deploying the CO2 heat pump system in a larger system that would make full use of the generated heat become clear in the KIWI Dalgard situation. As a pilot project that has not been replicated since, the KIWI store in Dalgard, Trondheim, has been built alongside a new residential unit of 5 flats whose heating needs are covered by KIWI.

As the past few years have proven the system does work but it has its own set of challenges. As the ASKO engineer, Staale pointed out, the manager of a system can increase or decrease the heat output of his own system, without affecting the cooling needs of the store. However, the challenges arise from the fact that the residential complex itself is not under the control of Vegar, the engineer managing the heating and cooling needs of all KIWI stores in Norway. He can remotely monitor and make changes in the KIWI Dalgard heat pump but he does not have access to the heating system and requirements of the buildings he is providing heating for.

Although none of my informants were willing to go into details, the fact that there are different managers on these two intertwined systems, seems to have generated enough issues that both Vegar and the Staale seem to be reluctant to pursue this line of research. While for AKSO the solution is simple enough since they own massive warehouses that, by necessity are built in or close to large residential areas, and have therefore access to established heating solution providers like Statkraft, the same solution may not be as readily available to smaller stores.

For one, it just so happens that in Trondheim Statkraft is close enough to ASKO that the latter could easily pump its extra heat in the former's already existing infrastructure. However, the heat loss, as well as the financial effort of developing an infrastructure that would take the extra heat from all the supermarkets in a large city to a central distribution system make the entire concept unfeasible.

From Statkraft's perspective, according to one of their engineers, Kent, they exist as a state owned company that needs to work at a very high standard of reliability and efficiency. While they do have several other smaller, re-heating plants spread out through Trondheim, and therefore they could absorb the extra heat from at least 2 other supermarkets in the area, they cannot be part of what is still an experiment. It is their attitude that proves once again that the CO_2 heat pump is a radical innovation that may thrive in the relative safety of its supermarket niche, and it may be encouraged to exist as such by the state, but it has not yet proven itself to the point where it will be accepted by the state as a viable means of generating heat.

The second aspect that the examples of ASKO and KIWI Dalgard are forcing us to consider is the fact that there are numerous towns and villages that do not warrant the existence of a giant heating provider such as Statkraft in Trondheim, and, therefore, there is no third actor capable of undertaking the managing tasks and the development of an infrastructure in those smaller towns. However, those very same towns and villages do need and are currently serviced by stores from either KIWI, Coop, or one of the other major supermarket chains.

As stated before all of the supermarket chains are dedicated to the proposition of making the transition to CO_2 heat pump systems and will, therefore, have to tackle the challenges of the extra heat generated by the new system, and also the moral responsibility behind knowing that they could provide a heating source for their surrounding communities that is cleaner and more efficient than their existing systems. However, without the aid of government level policies, as well as a governing body that would make the connections between the various actors involved, the CO_2 heat pump's true potential as a radical innovation may be lost.

I have attempted to draw the potential path from innovation to an established technology part of the landscape in the following figure that Geels introduced as part of his 2002 paper, "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study". (Geels, 2002) I have grafted upon it the potential growth direction for the CO_2 heat pump technology.

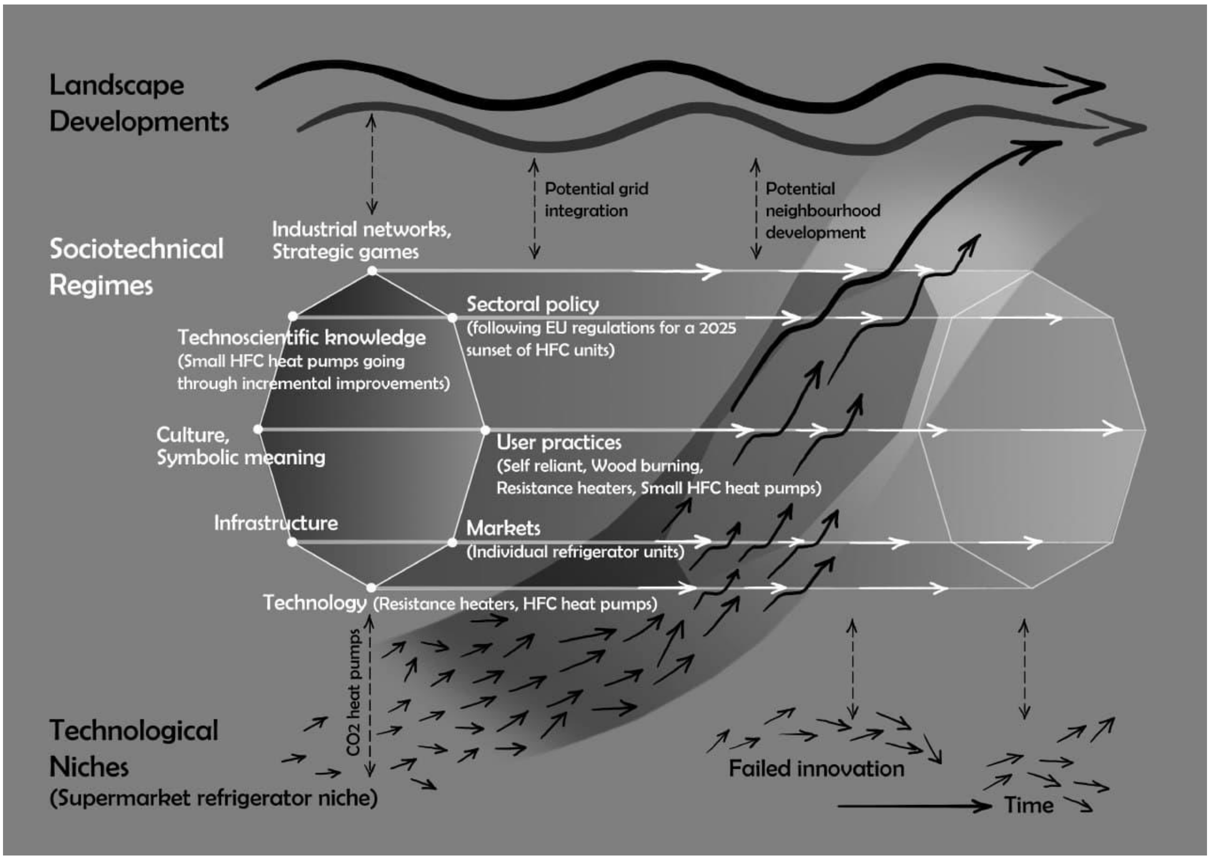

Figure 2

As I have tried to highlight in Fig 2, when considered under these constraints there are three potential solutions that can be followed at supermarket level. The technology is definitely there and it needs to be put to full use, which would mean in this case to breakthrough the current user practices of using mostly home based, self reliant systems, or to give up completely on the task and use the city grid. From the point of view of the supermarkets they can either distribute the extra heat generated by the heat pumps to one of the surrounding building complexes, or to partner up with an existing heating company and "sell" them the extra heat generated. The other would be to run the system at peak efficiency and count on the winter months when there is a need for heating to melt the snow and ice from the parking lot.

Lastly there is the option that the supermarket Meny has opted for: that is to optimize the way the extra heat is dealt with. By making the switch to glycol instead of directly running the CO2 to the cooling phase the process is optimized and the energy usage stays the same as in the other systems.

While introducing glycol in the process of dispensing of heat may not seem like that big of a chance it actually marks the first schism in the transition to using CO2 as a cooling fluid. It is a technique introduced by the engineer handling the cooling and heating needs of all Meny stores, Erik. By using glycol during the process of dispensing with the heat generated by the cooling systems, he is taking a radically different approach from the one employed by stores like ASKO, Rema 1000, and KIWI. (Meny System Admin, Trondheim, 2019, Phone Interview).

By introducing glycol in the cooling process, the Meny system is efficient enough that most of the heat generated by the heat pumps is used in the stores. However, besides the regular heating needs that a store would have, Meny also has a working kitchen and meat preparation area. That translates into a larger need for hot water that makes use of the extra heat generated by the refrigeration systems.

In short, the Meny system is optimized on several levels so that it does not need an exterior heat user such as a complex of buildings, to make the use of CO2 efficient.

It is interesting to note that this difference in approaches marks the first epistemological schism in the approach to using CO2 as a refrigerant. The CO2 to air cooling method used by Rema 1000 was essentially proposed and is currently improved upon by the refrigeration department at NTNU at the Department of Energy and Process Engineering, headed by Professor Armin Hafner. The CO2 to glycol method is spearheaded by engineer Erik Halstensen and is implemented in the Meny stores. Both proponents are actually former NTNU students in refrigeration, separated by just one year in graduation generation, Erik graduated in 1975 and Armin in 1976. As such they are both fairly influential voices in the research community, and the impact of their views can already be felt.

Whether their approaches will turn out to be competing niches similar to the clash between HD-DVD and Blu Ray, or if they will eventually merged into an overarching solution, remains to be seen. The obvious advantage of the glycol solution is that the stores do not require a nearby heating plant, neighborhood or parking lot to absorb the extra heat being generated. On the other hand, the very fact that the CO2 to air solution can include the solution to the heating needs of an entire neighborhood can be a positive asset as well.

The CO2 to air strategy can also work as a stand alone system. It was implemented through a program named Copen, and was the product of a collaboration between Rema 1000, NTNU, SINTEF, Danfoss and Norges Gruppen. It was centered around implementing an entire host of niche technologies that would support and make use of a central CO2 heat pump that would cover both the cooling and heating needs of an entire store. The test subject store that was used was the REMA 1000 store in Kroppanmarka in Trondheim.

The heat pump used here was tuned for the specific needs of the store by the NTNU research group and was designed to fulfill multiple tasks including to channel the extra heat produced in heat well. The adjacent niche technologies that were implemented are described in further chapters so they do not need to be described here. For the purposes of the current discussion it should be noted that, even though the entire system was deployed in 2012, and is hailed as the first of its kind, it was not reproduced in other REMA 1000 locations.

Parts of that technology are still being used throughout Norway and newer stores are built with CO2 heat pumps, but that makes the Kroppanmarka locations special is the host of niche technologies being used there. However, even according to the description of the NTNU researchers that worked on the implementation of that system, like N1, the heat pump technology in use there is already outdated. The system is still seeing massive improvements which might also be the reason why complete solutions might not be further rolled out in other stores.

In this context, complete solutions refers to systems that are being designed in concert with other niche technologies in an attempt to create not only a system that is on par with an HFC powered system, but one that would outclass the hydro-florocarbon systems. In stark contrast with the CO2 to glycol solution, the CO2 to air solution requires a concert of other technologies, including the minutia in the design of the heat pump itself to keep being tweaked and improved.

A new avenue of research that is currently being deployed as a result of the NTNU and REMA 1000 cooperation is being developed by N1. He is working on implementing a double refrigerant system that will be used in a chicken processing factory to be opened in Orkanger. He is using both CO_2 and ammonia as refrigerants and developing a dedicated cold storage unit that would steadily charge with cold. The reason behind using a cold storage unit has to do with the fact that the new factory will be working on a single shift rotation. That means an 8 hour a day, single work shift that would be working between regular working hours. Unfortunately, that means the factory would be using massive amounts of energy towards the afternoon, after all the processing has been done, to flash freeze the meat. That process takes up a lot of power, and, in Norway, electricity has one standard price for a certain consumption, but if anyone consumer draws in large amount of wattage in a very short amount, using peak power and therefore straining the entire system, then they have to pay a lot more.

N1's project has to do specifically with building a cold storage unit where water mixed with salts is slowly cooled down to below 0 degrees Celsius during the 16 hours when the factory is not working. Then, when the factory reaches its peak consumption, the refrigerant is then pumped through the slush of cold water, and then further cooled down with the heat pump. However, because the heat pump is working to bring down a fluid that is already at -4 degrees Celsius, it is using less energy from the power grid, thus avoiding a burst of peak consumption at a specific time.

What makes the entire system even more interesting is the use of ammonia as a refrigerant. Ammonia is the oldest refrigerant that is still being used. The fish producing industry is still relying heavily on Ammonia because it works and has always worked just as efficient as HFCs. The problem with ammonia is that it is extremely toxic if it comes in contact with food. However, N1 has devised a system where an ammonia heat pump lowers the temperature of the already cold fluid coming from the cold storage unit, and that fluid is used to cool down the CO_2, which is then used as a refrigerant in the second heat pump and then used to freeze the meat. Thus, only CO_2 that has never come in contact in anyway with the ammonia, is actually used in the freezing of the meat. And yet the system does take advantage of the lower running costs of an ammonia-based system.

The introduction of ammonia as a potential refrigerant marks another potential schism from the pure CO2 systems, but it should be noted that there are two crucial differences from the one introducing glycol. From a technological perspective, the ammonia is introduced on the cold side, meaning it comes into play to cool down the CO2, not as a means to take on the resulting heat.

More importantly, from an epistemological perspective, this line of research is taking place at NTNU under the supervision of Professor Armin. It is therefore a means of continuing the research line of CO2 to air, and can be viewed as a different attempt at making that technology more efficient.

The other important aspect to note about the introduction of a second, ammonia-based refrigeration system, is that it marks the point where the new CO2 based cooling technology is branching out into a different industry, the meat producing industry. The step is an important one because the cooling needs of this industry are far greater than those of a supermarket. The challenge that drove the collaboration with NTNU is no longer focused on finding a match for the HFC refrigerant powered system.

The challenge with the poultry industry has to do with the need to flash freeze the processed chicken every day at the end of each work cycle. That means the freezing plant needs to operate at full power for just a couple of hours every day. However during those hours the power drain can be massive. It is actually so large that, in accordance with Norwegian pricing regulations, the price of watt/hour would increase dramatically. Therefore, it is not just that the power grid would come under considerable constraints during those few hours, but the factory itself would end up paying a lot more for its energy needs, according N1, a PhD researcher at the Refrigeration Department at NTNU. (NTNU Phd, Trondheim, 2018, Personal Interview).

In order to stretch out those energy needs throughout the day, thus decreasing the demand on the grid, the plant needs to be able to generate and make use of cold energy throughout the day. The way that N1 manages that situation is to create cold storage batteries that can be cooled down during the non-active hours, and can be afterwards drained when the factory needs to use the day's production. Once the CO2 has been used in the circuit to freeze the meat, it still expels the heat it has trapped out into the air, thus making this a CO2 to air system, but is then circulated through the cold storage batteries, further cooled down there, and then goes on to be cooled by the heat pump, which now, has a lot less work to do, and requires, therefore, less energy.

To sum up, the radical innovation that is at play in the Norwegian supermarkets is the implementation of CO2 heat pumps. The supermarkets themselves are a niche created by financial giants like Norges Gruppen where they can encourage the transition to CO2 heat pumps while allowing different agents to work out the inherent problems of the new technology. Currently, the big directions have to do with the way a CO2 heat pumps' generated heat can be managed. One avenue of research has to do with optimizing the heat pump towards cold generation and using glycol to manage the extra heat, while the other employs a host of other niche technologies to drive down the overall energy foot print of the supermarket using the CO2 heat pump. The following chapters will deal with these alternative technologies that need to work in concert with the CO2 heat pump.

7.2.3 Innovations in Heat Storage

The REMA 1000 Kroppanmarka store introduced a new cost cutting measure by using heat wells. These are boreholes dug deep underground to take advantage of the fact that at that depth the temperature is a constant 4 degrees Celsius. In the first-year refrigerant is first sent down underground through these boreholes, so that the heat pump only works to lower its temperature from those 4 degrees. The significant aspect about the boreholes is that they are a byproduct of a completely different research avenue. Although the need to dig narrow holes in the ground is not new, it was developed and significantly improved for the oil extraction industry according to PhD researcher from NTNU. (NTNU Phd, Trondheim, 2018, Personal Interview)

NTNU is, part of research project with the oil and gas industry as well and they are able to use the latest technologies developed for that field. This only goes to exemplify how the research consortium benefits by its financial support of research conducted by NTNU and SINTEF, and also how technology developed in one field is easily ported in a completely different field. As Norway in general is making the transition away from oil extraction there are more and more extraction companies refocusing their attention on heat wells.

The boreholes also work as a heat storage unit because during the warmest months of summer when even in Norway there is no need for heating, the excess heat from the CO_2 system is pumped into the ground. Over the course of its first year of use that system further raised the constant temperature underground to 7 to 8 degrees Celsius. So, in winter, the heating system of the store uses the excess heat generated by the CO_2 system while its working in the freezers, but it also gathers up more heat from the underground source. It is worth mentioning that this means an NTNU engineer needs to visit the store for maintenance at least twice per year, to change the system from pumping heat into the ground during the summer months, to recovering that heat back up during the winter months.

However, simply storing the heat in the ground is usually not enough. According to Vegar, the project leader from KIWI, their newer stores are built, when possible close to large buildings that can make use of the extra energy. The KIWI Dalgard store that was recently built in Trondheim is generating enough heat to cover the needs of a nearby 5 story residential building that were built at the same time as the store and their heating systems were integrated with the supermarket itself. They are also using heat wells, but the ground is already saturated, and they are ensuring 100% of the heating requirements of the nearby building. And yet they are still forced to dump some of the excess heat into the atmosphere. That heat does not have any negative effects on the atmosphere, but the very fact that it is dumped outside is a failure in itself that the newer KIWI stores are trying to compensate for.

As several interviewees have hinted, the failure in the case of the Kiwi store stems from the fact that the two systems, the heat pump from the store and the heat distribution system within the building are not designed or integrated by the same person. Of course, that would mean taking on a series of responsibilities that make the task itself quite daunting. (ASKO System Admin, Trondheim, 2019, Personal Interview)

The more interesting potential for an innovation in storing the heat generated by a supermarket's CO2 heat pump is the one proposed by the ASKO, where they would collaborate with a company that is already providing heat to a city. That way, the extra heat can get used but there is not pressure put on the cooling system of the supermarket. While proximity to such a plant may make this solution difficult for some situations, in the case of ASKO and Statkraft, the challenges stem more from a difference in policies and administrative involvement, than from any technical challenge.

7.2.4 Innovations in the Lighting System

The reason why the Rema 1000 Kroppanmarka system is called a fully integrated system is because it handles the entire needs of the store through a single unit. However, there are further cost cutting measure that have been implemented. One of the most significant ones is the fact that all fridges use glass doors, including the deep freezers. That alone translates into an energy cut of around 20 per cent according to N1. The fact that they system is fully integrated and uses heat wells, means another 10 to 30 percent increase in efficiency.

Further helping lower the costs is the fact that the store lighting system has been completely switched to LEDs. The lights themselves are controlled by an automatic system that also controls the blinds for the windows and an interior and an exterior light sensor. That means the system automatically adjusts the blinds to allow maximum light to come into the store from outside, and gradually increases the light from the LED system to compensate as needed. N2 estimates that just by removing the factor of human error and by making the switch to LEDs the energy efficiency of the store was increased by 5 percent.

The move to LED lighting is actually one of the common themes in all supermarket transitions to using CO2 heat pumps. Erik Halstensen who managed the transition for Meny also mentioned the switched to LED lights as a cost cutting measure that would offset the price of using a CO2 heat pump. While the system employed at MENY is optimized for cooling and uses glycol as part of the heat management system, Erik is still working on improving the overall energy efficiency of the store.

7.2.5 Innovations in Alternative Refrigerants

Another technology that was first used in the REMA 1000 store is that of hydrocarbons used as refrigerants. The most common hydrocarbons being used is methane and propane. While methane is usually used as a fuel, where it is burned, and has a wide range of damaging environmental effects, its use as a refrigerant is encouraged. The small amounts that may escape the system are too diluted to burn and do not affect the ozone layer in any way. The amounts currently being used are under 50 grams, so they cannot power freezers or larger units. However, small, standalone units can be run on propane being used as a refrigerant. The advantage with hydrocarbons is that they are just as efficient and readily available as HFCs. The only disadvantage with hydrocarbons is the fact that they are extremely volatile and, when used as refrigerants, they are forced into pressurized systems, which is the very definition of a bomb. However, at 50 grams, even if the entire gas container were rigged to explode with its entire content, N2 assured me that it would not even move the fridge off of its initial position. The interesting aspect about hydrocarbons is that by early next year the EU regulations may be lifted to 500 grams which will allow propane-based systems to power similar refrigeration units as CO_2 and HFCs are able to power at the moment according to N2. The reason for the increase quantities are ever improving sensors that perfectly monitor and can account for losses of refrigerant, which makes the entire system a lot safer. (Trondheim, 2018)

Even though REMA 1000 was one of the first company to use hydrocarbons as refrigerants, the system is now so widely spread that most standalone refrigeration units in stores in Norway and Europe are most likely using them. So, it could be argued that although the new refrigerants are still the niche technology being slowly rolled out, parts of it have already taken over the market becoming themselves part of the socio-technical regime.

7.2.6 Innovations in Energy Generation

Besides finding new ways to more efficiently use up the energy provided from the grid, AKSO, REMA 1000 and KIWI are looking at solar panels as the means to generate extra energy for the store. Most supermarkets are in this situation because they are designed as standalone structures and they are, in a sense, wasting a lot of space on the roof of the building. The KIWI store in Auli produces enough energy from its solar panels to the point where it can sometime have extra reserves that are being send back through the state-wide grid.

However, there are several unique challenges raised by solar panels. For one, their maximum potential is reached only during the summer months when the sun stays high in the sky for long enough periods. The effect of solar power is lessened on cloudy days and it can be greatly reduced by layers of dust covering the panels. Besides the need to constantly clean and protect the panels, supermarkets or even companies trying to deploy massive fields of solar panels are also plagued by the fact that major technical problems cannot be addressed.

According to Vegar, project leader for KIWI, the manufacturing plants in China keep going out of business and new ones are being opened to fulfill customer needs. However, with each new closure, the technology and, more importantly, the responsibility for the maintenance and the warranty of the product keeps changing. That results in these various stores having to change their entire solar panel profile every few years when inevitable failures do occur. The entire situation could be avoided if the manufacturing plan would stay open because then they could just reorder the needed part, but, because there is no one to order from, they are in the un-enviable position where they need to replace the entire system. It is actually for that reason that the new store being open by KIWI in Hokksund, although aiming to implement every bit of technology that can be used to reduce the store's carbon fiber footprint, is not going to use solar panels.

KIWI is not giving up on the entire solar panel project. They have seen that it is efficient and now the parent company, Norge Gruppen is investing ten million krones in buying new solar panels. The reason for the investment does not have anything to do with the use of the panels but with an attempt to encourage the development of this type of industry in Norway. Because there is not such a big demand from the Norwegian market for solar panels, there are no established market leaders that could provide a steady flow of products and services for the market. So, by investing at this level, Norge Gruppen is attempting to show different market providers that there is, in fact, a need for this type of products and services.

And their attempts have not gone unnoticed. On this level at least IKEA is starting to rollout a solar panel program in anticipation of the moment when they will also need to make the transition to CO2 heat pumps. According to Joachim, the technology expert at IKEA Trondheim, the way forward for them will likely involve the acquisition of a company that is already specialized in solar panels. Unlike the supermarket chains in Norway, IKEA truly operates as an international conglomerate and can therefore afford to look at the entire European market when making the move to solar panels. Much like REMA 1000 they have their own, in-house specialists that are groomed for various key positions when they will start to make the transition.

I raise the point of what is in store for IKEA because they have proof that they experiments conducted at the supermarket level in Norway are being mirrored in other areas as well. They are already taking active steps towards getting ready to implement the solar panels technology in preparation for the 2030 deadline for making the switch to the new CO2 based technologies.

In conclusion, by being closely involved with the various research projects at NTNU, REMA 1000 was able to be one of the first stores to implement an efficient CO_2 system, to make the change to heat wells, to take advantage of the latest lighting solutions, and had access to the latest market research that convinced them to use closed fridges instead of the open, less energy efficient systems used by their competitors.

On the other hand, however, KIWI has decided to rely on traditional providers for these technologies. They may not have the latest technology available, but they do have tried and tested systems, and systems that can be relied upon to be serviced and repaired the system with ease. They may try to encourage the industry to come up with new offers, but their choice is to rely on proven, established providers in each field of innovation. While REMA1000 is proving itself as the niche market where the new technologies are being developed and constructed, KIWI takes up the role of removing the obstacles to market that would otherwise trap those innovations in the little-known back rooms of the supermarkets.

The solution ASKO has taken was to allow a much greater level of freedom to their "in house" engineer. They are employing the current technology that can be bought from established manufacturers, but they are tweaking the technology to perfectly match their needs. They are also aware of the limits as well as the potential of the technology. In this respect it is interesting to note that there is a definite difference in attitude towards the potential of the technology. While KIWI is actively researching new ways to interact with the community surrounding them, projecting an image of ecological awareness particularly because the people living in this area are young, successful, and thus part of a group that is more inclined to appreciate and get involved with this type of ecological project. On the other hand, ASKO is a lot more focused on improving their own CO2 footprint. It is important to note here that there are several ways in which Kiwi is adapting their approach to the precise geographical Their involvement is mostly academic in more ways than one. They are developing their own technology, but they are also actively involved with NTNU, allowing the students in the refrigeration department to visit the plant several times per year. Also, having talked with the main engineer there, it is worth noting that he takes an active role into passing on his knowledge and his views on the workings of a CO2 heat pump.

The only thing to add in the discussion on the use of CO_2 as a refrigerant is the obvious fact that the use of the extra heat generated by the system can only be used in an economically meaningful way in countries with an average temperature similar to that of Norway or below.

In fact, N2 was saying that even Oslo is too far south and therefore in a warm enough climate that the cost reducing benefits of using the extra heat are not enough to be implemented as such.

For that reason, N2 is involved in a parallel project called MultiPack. As part of that project he is working on improving the actual system using the CO_2. The technical aspects of the project here are more complicated, but in essence a heat pump ejects pressurized refrigerant into an expansion tank and that process cools down the refrigerant to whatever temperature is needed for the refrigeration unit.

In an attempt to make the system more energy efficient the current technology being used in lower latitudes involves double ejector systems. However, the more parts a system has, the more expensive it is. Currently, the systems being used as far south as Italy are actually more energy efficient that the ones using classic HFCs, although they are more expensive when installed. The difference generated by the energy efficiency and the fact that HFCs refrigerants are much more expensive than CO_2 means that, over the course of a decade, the initial higher investment is recuperated. Still, the Multipack project that N2 is a part of, is looking into methods of simplifying the refrigeration systems being used in the south. The aim is to create a much more efficient ejector system that will allow the return to a single ejector system, thus simplifying the system, bringing the costs down. N2 is also betting on lowered costs for the system as it is being adopted by the rest of the stores in Europe. The use of the latest CO_2 refrigerant technologies is not as advanced in the rest of the EU as they are in Norway, which means producing the components needed is still a niche market and therefore an expensive one. However, because of the EU regulations phasing out HFCs, N2 is betting on an increased demand which will drive the price of components designed for efficient CO_2 systems down. And of course, because REMA 1000 has such a close relationship with the NTNU research team, they will get first crack at using the new systems in their stores that are located further down south and on the West coast of Norway.

To sum up, REMA 1000 is pursuing a radical innovation strategy, working closely with its partner in the same city, the NTNU department of refrigeration, to develop and implement the very latest trend in technology.

KIWI on the other hand is relying on proven technology. They are just as aggressive in their goal of reducing the store’s carbon footprint, but they are taking an incremental approach towards innovation. Their strongest strategy relies on the fact that they have already rolled out

6 stores that are using CO_2 heat pumps with various auxiliary systems. They are constantly monitoring the performance of their existing stores and so that every new build can benefit from the latest but also most efficient technological developments. So it is, for example, that their latest store being built in Hokksund does not use solar panels, although the company has not given up on their use altogether.

ASKO, and by extension COOP, is taking a middle ground approach: they are staying in close contact with NTNU, "poaching" as it were the technologies that are proving to be most reliable, and are in a position where they could easily change to a more aggressive approach, employing a radical innovation strategy. They are actually branching out into a parallel technology, that of using hydrogen as fuel for cars. That technology is only tangentially pertinent here because the process of obtaining hydrogen, which they do on site, also generates a lot of heat. In this sense they are actually the closest to using the CO2 refrigerant heat pump as an incremental improvement rather than a radical one. That in itself is ironic since the system administrator from ASKO was the first one to point out the potential of integrating his system with that the of the nearby Statkraft facility. (Trondheim, 2019)

MENY stands apart from they other supermarkets in Norway because of the way they handle the heat generated by the system. By using glycol in the process of dispensing of the heat generated by the CO2 system, as well as maintaining the pressure in the system as low as possible, and thus heat generation is also particularly low, they are able to keep their energy usage as low as possible while. It could be argued that they have managed to smoothly integrate this otherwise radical innovation and implement it at the entire supermarket chain level. However, it should noted that MENY is nearly unique among the supermarkets in Norway in that they have a fully working kitchen and kitchen staff. They handle every cut of meat from fish to poultry to pork, and seasonal meats like mutton, and, therefore, need a lot of hot water to maintain the level of cleanliness demanded by Mattilsynet, the Norwegian Food Safety Authority.

7.3 System Failures

Delimitation in the Diffusion of Technology

The most curios system failure in my opinion and one that will need to be further delved in during future research is why these technologies are not advertised more openly generating a delimitation to the diffusion of technology. The technologies discussed so far are part of multiple and different research papers and are therefore open to the public domain.

Furthermore, there is a growing community focused on sustainable living and decreasing their carbon footprint who would probably be convinced to stay loyal to the one local store that is just as committed as they are on implementing every sustainable technology resource at their disposal. My own theory is that advertising too boldly the state-of-the-art technologies being used by the store would constitute a hit against modesty.

To put it succinctly, janteloven is the standard Norwegian life philosophy that is best described by, ironically, a Japanese proverb: “the nail that stands out gets hammered in”. In other words: too much advertised opulence or even excellence, is seen as socially unacceptable and shun by most Norwegians (Karin, 2017). As a result, advertising too much the use of these technologies would actually deter clients from coming into the store, and it would actually clash with the general predisposition of most Norwegians towards modesty.

A second possible theory arose from further discussions with both my informants seemed to confirm this theory. N1, a Norwegian himself, is actually frustrated by the lack of advertising and public awareness. He has an alternate theory that focuses on the gap between franchise owner and franchisee. As an example, most REMA 1000 stores exist as franchises. The Kroppanmarka store itself was built with financial support from the franchise owners, and they are the entity referred to throughout this paper as the ones investing in the new technologies.

The question then arises of who is responsible for the local Kroppanmarka store. The current store owner, which N1 actually referred to as “daglig leder” is concerned with stocking up the shelves and making sure the aisles are clean. It is obvious by the fact that the in stores promotions happen in concert at national level, that the marketing aspect of the business is left in the hands of the franchise owners. And yet, control over dozens and dozens of stores means that the top marketing management level has little time or concern with a single store in Trondheim.

On the other hand, the “daglig leder” is used with the fact that marketing decisions are made for the entire chain store and has very little time or financial backing to organize her own marketing strategies. It is important to note here that this is N1’s theory, one that I value and appreciate, but that still needs to be worked out through further interviews.

Lack of Governmental Involvement

A second system failure has to do with the apparent lack of intentional effort being put in at governmental level to promote the use of CO_2. They are founding the research efforts through the Research Council of Norway, and the new regulations coming through the EU are increasing the costs of refrigerants, which means that more and more stores are switching to using CO_2. The REMA 1000 Kroppanmarka is no longer the only store using CO_2. Most of the other stores, in particularly KIWI and MENY, have already made the transitions, or are in the process of making it, but they have chosen to absorb those costs and that makes the entire process take place at a much lower pace. However, the lack of a system wide policy capable of making full use of this new technology is severely limiting the speed with which the system could evolve. The potential is there but, without policy development, it is unlikely that all of Norway's supermarkets and heat producing systems will coordinate in order to integrate their efforts.

Lack of Established Vendors in the Market

The third system failure has to do with the availability of the technology on the market. As K1 was pointing out, KIWI is focused on providing a reliable level of quality to its clients. They cannot afford to be put in a position where they need to wait for specialists from Germany to come and troubleshoot system problems every time there is an error. They are sending signals into the market that there is a demand for locally grown specialist companies that would take up the responsibility of installing and maintaining the newer heating and cooling technologies. So far, they have had to scale back on the solar panels project because of the lack of local specialized providers.

Finally, I have asked K1 as well about the reasons why KIWI is not advertising more openly, at least at the level of the stores that are using the technology. For him the reason has to do with the fact that KIWI as a nation-wide store has not found yet the one solution that would be rolled out to all stores. They are still trying out new options in terms of the CO_2 heat pump architecture as well as the auxiliary technologies that are required to use it. He says that the moment KIWI is sure of the technology it is planning to use, they will roll it out and advertise as such. However, because of their current reluctance to advertise too boldly the technology does not diffuse out to other consumers, in particular small homeowners who would probably be interested in using it.

7.4 Alternatives to the Alternative of Using CO2 Refrigerant

One of the big questions in sustainability transitions has to do with the question of what voices remain unheard, and one of the most obvious ones are those of the manufacturers of HFCs. Given that their product is damaging the ozone layer and that EU regulations are being implemented on phasing them out, it is easy to see why they would be cast in the role of the bad guy. However, N1 spoke during our interview of a new class of hydrofluorocarbons called HFOs. These new refrigerants, although still byproducts of the oil and gas industries and although they are still being produced as upgraded versions of HFCs, have a much lower ozone layer coefficient, some of them coming as close as 2 or 3, in comparison with the 1 that is represented by CO_2. Still, N1 worries about the secondary effects of these gases. Although in their purest form HFOs have been shown to have a reduced effect on the ozone layer and on the environment, they exist as complex gases. When these gases dissipate in the atmosphere they break down into their base components and interact with other chemical products that already exist in their natural state. N1 worries that the effects of these new chemical secondary products have not been studied carefully enough, and thinks that they might prove to be just as toxic as the old HFCs. So even though HFOs might still see some sails due to the lowered prices their compliance with the EU regulations can obtain, there is still very little chance that they will have a future. It is also worth noting that no research conducted at NTNU or SINTEF is focusing on the use of HFOs, so their future in Norway has already been written off.

In terms of alternatives to the use of CO_2, N2 sees hydrocarbons as a potential alternative. He seems certain of the fact that the newer regulations will see the increase of hydrocarbons regulations from 150 grams to 500. I taxed both him and N1 to come up with even the more SF worthy alternative that they can see for the future or refrigeration, and besides a battle for supremacy between CO_2 powered systems and hydrocarbon powered systems, none of them could see an alternative.

Ammonia is still a very efficient refrigerant, but it is too toxic to be used in systems that come in contact with food, which means it will probably be used the way the chicken factory in Orkanger that N1 is designing will be using it: as a first stage refrigerant allowing for an optimized use of CO_2.

Heat wells and cold storage units are still being developed, and future research will look into the state of technology being used there, but neither of these two technologies can exist without the use of a heat pump. The advantage in developing the cold storage technology is that it has a leveling effect on the amount of energy being used at any one given time. Furthermore, because the cold storage unit represents an effective barrier between the coolant and the refrigeration unit, it might be the one way in which ammonia could be used in supermarkets. Still, even if it is used in concert with CO_2, the cold storage unit can be seen as an alternative to the classical solution. Still, these technologies, together with the more efficient refrigeration units, LED automated lights, can only work in concert with CO_2 and hydrocarbons in the attempt to make future systems even more efficient. In fact, it is interesting to note that when I asked N2 about the Kroppanmarka store he was quick to dismiss it as an early proof of concept example, but as one that is outdate and no longer a match for the technologies currently being developed. The newer technologies are not only optimized to work better, they are focused on using CO_2 as a liquid. The reduction in energy usage would only be to about 10 percent, but it is an advantage on which REMA 1000 is hedging its bets for a more sustainable refrigeration unit.

8. Wood as a Complete Building Solution

The second area of research that has found a safe harbor in Norway is the implementation of wood as the main building material. So far, the main problem with wood is that, being an organic material, it has a natural elasticity that can add several layers of distortion when used in large buildings. Norway has a long tradition in wooden structures, and they have achieved a particular high level of efficiency in the roof construction of old churches that can be made out of wood, but the technique is so complicated that most structures still use concrete or bitumen roofs. However, new developments in the design of wood structures are making it possible for buildings as big as supermarkets to switch back to this traditional material. By using cross laminated timber Norway has been able to build the tallest timber building, a tower of 85.4 meters. The advantage of using cross laminated timber is that the wood no longer becomes compressed when under weight. A similar technique has enabled the construction of new student housing in Moholt, Trondheim, where although the core of the building is still concrete, the outer structure is completely made of timber.

The main advantages of using wood is that it is a natural capsule for CO_2 – that is to say trees use CO_2 to grow and they release it when it is burned, meaning that any tree that is used without it having to burn to provide energy represents just another capsule of CO_2. Furthermore, trees exist or can be planted with the purpose of being harvested almost anywhere in Norway. For that reason, the KIWI store in Hokksund is actually being built entirely out of wood. Most of the wood is harvested locally, but there are some parts that needed to be imported from Germany.

Most of the following information about the many new techniques that allow the use of wood in ways that it was impossible or very difficult to do a few years ago are actually provided by one of the developers of these new technologies, an informant whose pseudonym will be G1. He works for a relatively small company out of Melhus, Green Advisers AS. However, while these technologies are being developed and tested on unrelated projects, a sports hall here, a garage there, the one big player in the market is also KIWI. Their philosophy is that they are looking for solutions that can be easily expanded to cover the entire network of stores. For that reason, they are not in contact with Green Advisors but are relying on larger providers from Germany for some of the key products that they require. However, just as in the case with the solar panels, they are looking to encourage the development of local technologies that would be then much cheaper to implement.

8.1 New Socio-Technical Regime

The basic representation of a modern building starts with a concrete foundation, dug deep underground. From that foundation high metal beams or struts create the outline of the building and of the roof. An exterior layer of metal or wood is laid down, then follows a layer of mineral insulation, and then a layer of plasterboard or wood paneling. The roof is covered in shingles that are commonly made from one of the many byproducts of the oil and gas industry, usually tar infused cardboard that is meant to stave off the weather for anywhere between 20 and 30 years.

The building industry is actually a lot more complex, but as a starting point in my discussion with G1 we decided to simplify the process to its bare minimum. The important technological background that the new technologies are developing against is one that uses steel, concrete and byproducts from the oil and gas industry. There is also a design philosophy that is being improved upon. Current designers focus on using the cheapest materials that will get the job done, and that will meet the client's requirements. The designs themselves focus entirely on aesthetics and are built with a focus on making the most out of those cheaper building materials.

8.2 Innovation Niche

The technologies being developed by G1 are backed by investments from the Research Council of Norway. Wood is a much more sustainable building material than the alternatives being used today, especially if it is harvested from forests grown specifically for that project. For that reason, it could be argued that the Research Council has no need for further motivation than the fact that wood is a cheap and sustainable alternative. However, there are two other general motivations that speak to the reasons for their generous investments.

As Geels points out in his “Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study”, niches technologies have a better chance to develop if they grow out of a tradition specific to that country. The many stave churches spread across Norway are what inspired G1 when he started his series of technological developments and are what continue to inspire him. His ultimate goal is to be able to build an entire building out of just wood, including the nails. The goal may not be so outlandish as it seems, considering the fact that most of the technologies required do already exist, although they may not exist in their optimal form. And that is where the niche aspect of Norway comes in, because of the country’s tradition of wood working combined with its willingness to invest in sustainable technologies.

Still, no matter how willing a country is to invest in new technologies, those technologies need to become affordable enough to the point where one day they can stand on their own. For that reason, G1’s first innovative decision was to re-think the way building designs were done. The main problem any on site builder has to content with is the standard size of the materials. As wood leaves the forest where it was harvested, it is cut in 4.8 meter long pieces. The thickness, width and shape of the wood will vary from plank to strut to support beam, but they will all measure 4.8 meters. G1’s first innovation was then that he started to design all the building he was asked to handle so that they would use the entire length of the wood being provided. He is reluctant to use the words “zero waste” but that is what he is aiming for and what sets him apart from the rest of the competition.

In terms of costs savings, it may not seem like a lot, but he has been able to build a profitable business around that concept. Whereas most other builders need to cut most of the beams and struts that come their way so as to fit their construction needs, G1’s carpenters simply lift the beams into place. By making those savings G1 can afford to use much stronger, high quality types of wood, predominantly oak.

His other focus is also aimed strictly at the quality of the products his buildings are using. He follows the path of the material he is working with from the forest to the building it is integrated in. Over the years he has developed a strong relationship with every person on that chain, from the owner of the nursery where the trees are raised and then fell, to the carpenters building his designs. That also allows him to impose his own perspectives on the philosophy of working with wood. At the level of the company processing the wood he is dismayed by the wasted saw dust that results. One of the ways he is dealing with that is to ask the company to lower the level of moisture in the wood, as it leaves the factory.

Currently, wood processing plants burn saw dust in the process of drying the wood. However, the processing of wood creates massive amounts of saw dust and not all of it gets used, but also the wood leaving the factory does not have the level of dryness that would meet G1's expectations. So, his solution is to bring these two problems together to solve each other out, to where the factory would use more of its wasted saw dust, and the wood would leave the factory at a higher dryness level.

From the point of view of the Research Council of Norway, this level of commitment and zero waste is a strong enough incentive to further finance G1's project, but there is also a second, even more enticing incentive. Because these types of buildings are designed so that less building material needs to be cut and adjusted on site, it takes a lot less for a carpenter to get a particular job done. As the interviews detailing the intricacies of the heating and cooling industry have shown, almost every aspect of Norwegian life needs to deal with the high price of labor. Therefore, the fact that G's projects take less time to be setup, means further cuts in costs. Those cuts then reflect in the wages of the carpenters being used. According to G1, and my own far more limited experience, professional carpenters in Norway have to deal with an influx of massive workforce from lower cost countries like Lithuania or Poland, who are willing to do the same jobs for less pay, and usually pay that often is not reported or taxed. By reducing the time, a carpenter needs to spend on the job, G1 manages to achieve enough of a profit margin to where he can demand of his contractors that they use only professional, above the board, taxed carpenters. Those carpenters are still, in many situations, Lithuanians, but they are paid at the standard salaries expected by the Norwegian carpenters and the money is properly taxed. The second effect from the point of the buyer is that the contractors who are actually handling the construction work, no longer feel pressured to hire whatever carpenter will work for less money, and they can hire based on performance only.

At this point there are at least two clear incentives both for the Norwegian government who is financing the bulk of G1's work, but also for the private companies that benefit from his innovations, to continue to invest in his work. The first is that he is able to drive waste down, all the while making the transition to a sustainable building material. Second, by reducing costs, and by selectively choosing the companies he is willing to work with, he is able to impose a standard of workmanship that can only be achieved through high quality workers being paid imposable, Norwegian level incomes.

The goal of pursuing a zero waste building philosophy has led to the development of a different technology as well. The original concept comes from Germany where they created one of the first wood based insulations. G1 was able to import that technology, secure founds from the Research Council of Norway, and from industry partners that are interested in further improving on the concept. The funds were granted and at the time of the interview, G1 was able to show me a sample that he had just received from the partner manufacturer. The advantage of the new type of insulation is that it is made out of the ever problematic saw dust. Saw dust is one of the last wasted products from the manufacture of wood buildings. The improvements brought in are a patented secret, as is the formula through which the new insulation is created. However, it has not artificial fibers, it is mostly made out of wood saw dust, and it does not trigger the allergenic reaction that traditional mineral wool generates. As a proof of concept, and also as a proof to himself, G1 made a pillow out of the first batch of insulation that the new research has provided. Except for the fact that it is not as soft as a regular pillow, he felt no ill effects.

Of course, one person having a good night's sleep on wood insulation material is not a proof within itself, but that is why the G1 was very guarded about revealing too many details. His focus is currently on officially testing the new insulation and getting it approved to be used in public buildings, especially in schools since that is where most of the challenges are. The reason why this new development is important, besides all the other ones that apply to the new industry, is the fact that the new insulation does not require any special tools or suits to be installed. Any carpenter can just go from putting up the struts to adding the insulation. That cuts down on time wasted while putting on all the protective gear, as well as the need to spend money on the protective gear.

However, because Green Advisors is not as big a company as to represent a trustworthy business partner for KIWI, the latter has chosen to import their insulation material from Germany. According to K1, the project leader for the development of sustainable technologies within the stores, the cost of importing the insulation material is prohibitively high, however they have decided the effort was worth it just to be able to test the new material in a real-life setting. KIWI is in the unique situation here of being able to have real life tests of all these new technologies and their interaction. Currently K1 has a reporting system that allows him to check in on each of the stores that have any type of sustainable technology implemented. Sensors tell him just how much energy is being consumed or produced. Granting that there is no way for accounting for difference in weather between the different store locations, K1 will still be able to monitor the efficiency of the new wood chip insulation materials in comparison with the other stores that may still be using CO_2 heat pumps but traditional heat insulation.

At this point it could be said that KIWI and Green Advisors are working towards a similar goal while taking entirely different paths. Green Advisors are developing the wood working technologies that are embedded in the Norwegian traditions but inspired by technologies that exist. They are creating the niche for these new technologies to develop. KIWI on the other hand is spending a lot of money, importing the products as they exist today, creating a need in the market for these technologies to exist and thus encouraging manufacturers and technicians to expand their processing capabilities and eventually supporting the efforts of Green Advisors.

The new style of construction, including the new insulation material provides G1 with his best selling point. He does not do any advertising on his own because the new buildings speak for themselves. Among his past projects there are a number of sports halls that see a lot of visitors. The difference in air quality, as well as the workmanship that went into every detail is so apparent that new visitors always ask the owner of the building what is different about the building itself. They have a difficult time actually tracking down where the difference is, but they are aware and excited about the difference. The owner of the building then points out the differences between a traditional building and his own, and that is enough for any prospective buyer to get in contact with G1 and to learn about the intricacies of his style of building.

Finally, a somewhat older development, but one that is of particular importance from an environmental point of view are a new style of tile made out of wood. Traditional tiles are made out of carboard infused in a variant of tar and are therefore slowly dripping carbon together with other chemicals and heavy metals back into the ground and into the atmosphere. The effect is not enough to affect anyone house holder, but it is measurable at global level. There is also the fact that the traditional type of tiles needs to be changed anywhere between 20 and 40 years with a maximum real life expectancy, under ideal conditions of 100 years. So, G1 came up with a style of wood plates that can be used as roof tiles. They are much larger in size and therefore can be installed much more easily. They are also laid down following a specific design that lets air circulate easily and thus they get dry faster than regular tiles. From a commercial perspective the advantages have to do with the fact that the new tiles take less to be laid down, since they are bigger, and therefore their installation costs less. They are also less prone to be damaged by the passage of time. Official approvals and tests still need to be conducted but based on the example of similar wooden tiles used in the Norwegian stave churches, G1 is confident that the new tiles could have a lifespan of anywhere between 100 and 200 years.

K1 also confirmed that KIWI is interested in the use of wood as a roofing material but it presents one more challenge besides those raised by the saw dust thermal insulation. The wood tiles for roofing need to be extremely dense in order to prevent as much water from penetrating the core of the wood as possible. As a result, they are also extremely heavy so importing them from Germany would require extremely high costs in shipment. For that reason not even KIWI is interested in testing them out before they are developed at a local level and can therefore be created and transported locally.

Although this is not an exhaustive list of the new wood based designs, the conclusions that can be drawn are fairly self-evident. By combining a tradition of using wood as the main building material in Norway, with modern technologies, and taking advantage of the government incentives for sustainable technologies, G1 is able to develop newer and newer technologies. The new style of work is more sustainable for the planet, but is also more financially feasible which allows for the creation of new job opportunities in the manufacture of wood, as well as better paying jobs for the carpenters installing the new technologies. Of course there is no guarantee that once the technology goes mainstream and other companies, outside of G1's control being using them, they will maintain the high standards of pay and qualification for their works. The new types of heat insulation material and roofing systems are a challenge onto themselves because, once they become freely available, they will drive the cost of installation down. They are currently created with the state purpose of making their installation easier and, by the very nature of their manufacture, they are safer to use. For example, the use of mineral wool as an insulation material requires the use of protective gear, and, depending where it used, specialized machinery. The new, saw dust based insulation material requires neither so there is no barrier to entry in using it.

8.3 System Failures

My interview with G1 revealed also what the greatest problems are with the implementation of the new technology: he is already at maximum capacity in terms of the products he is willing to take on. KIWI would be an excellent partner at this point but for them Green Advisors is still a small company that has decades until it can prove itself as reliable enough for large supermarket chains to rely on them. An earlier point made about the wood working techniques was that the new technology is so self-evident that no actual marketing is required. Potential clients are attracted by the perceivable difference in the quality of breathable air in the new buildings and are pointed in the right direction by the current owners. However, that means that, at the moment, the distribution capacity for the new technology relies on a single company in Trondheim thus constraining the diffusion of the technology. The factory that is producing the new building materials is also selling them, but just as is the case with the REMA 1000 case discussed earlier, there is a shifting of the responsibility to promote the new tech from one entity to the other. That is not to say G1 has not been featured in several newspaper articles, and, in fact, he was very generous with his time during our interview, but he freely admits that he is not actively seeking to promote his innovations.

Another failure in the system is represented by the bureaucracy that is preventing Green Advisors AS from receiving all the certifications they would need for their locally developed products. At the moment KIWI is importing the thermal insulation from Germany because there is no certification as of yet for the one in Norway. There is a factory producing the new type of insulation but it is just enough for the projects handled by Green Advisors. Kiwi's policy on the other hand is that they want to be able to access anyone of these sustainable technologies as easy as it currently is to access the standard Glava insulation. The existence of a strong presence in the market would allow these technologies to be easily accessed as well as implemented more easily. The other signal that KIWI, and by extension all other stores is waiting for, is the presence of trustworthy specialists that can implement the new tech, and who can be held accountable afterwards if there are any faults with the product and its installation.

The paradox here is that, currently, we are in that uncanny valley where the products exist, they are better and easier to use than the traditional fabrics, but there are few specialists that can handle their implementation. Furthermore, there are several paths out of this valley, some where the product is disseminated to the point where non-specialists start using it in mass and drive down the cost of certified specialists, or where specialists manage to implement the new techniques and products and find some type of specificity that would make their services as important as before.

8.4 Alternatives to the Alternative on Wood Technology

In terms of alternative building technologies, G1 could only think of companies outside of Norway that are pursuing the same lines of research as he was. In terms of different building materials there seem to be very little that are in line with the concept of sustainability. There are bricks made from hemp, of course, but they are not ideal for the Norwegian climate, and they are just a variation on the concept of using wood as a complete building material.

When talking about the benefits of staying with the old technologies, G1 pointed to the reasons why he does not need any advertising. The quality of his buildings differs so much from those build with concrete and mineral wool insulation that visitors can feel the difference almost immediately. Of course, concrete and steel are the traditional building materials, but they are becoming just as outdated as wood itself was at the turn of the century.

9. Future Research

There are still questions left unanswered about the current transition to sustainable technologies in Norway. The electric automobile transition seems to be well underway, and the ever increasing number of manufacturers who are coming out with electric cars is certainly impressive. The advancements made in the refrigeration industry as well as the ones made in the construction industry seem to be equally impressive and have financial support from many avenues. Still, the technology does not seem to be picking up quite so fast. So, the question of why this side of the technology is not picking up quite as fast needs further exploration.

One of the reasons for this, as all the interviews have shown seems to suggest that there is very few public awareness focused on the matter. The implementation of locally developed wood working technologies has yet to be properly vetted and the developers of those technologies in Norway are taking a slow approach, letting the technology speak for itself. G1 is focused on proving the advantages of the technology to the point where he is trying to secure projects in Finland since the much lower temperatures there would prove to be a much better proving ground. On the other hand, KIWI is already confident that the technology is worth investing in, but they have no major retailer or provider that can implement the more advanced versions of the technology for them.

Other questions have to do with the parallels that can be drawn between the new versions of the wood working technology and the older versions. Currently there are still masters of the traditional stave churches, in particular roofers that are maintaining the roofs of the current churches. Exploring why that type of roof is not more used in Norwegians buildings might shed some light on the reason why the new technology is not being picked up.

Another direction in which the current research should be expanded is on experiences with the practical use of the technologies and the process of domestication of the technology. K1 went quite deep into explaining how the KIWI store in Auli was left without heating during the coldest part of the winter for several days because the team that had installed the heat pump could no longer be reached. Fortunately, because KIWI chooses to work with large, established companies, they were able to reach out to Danfoss, the providers of the tech and they sent out a technician from Germany. The problem was traced to a single valve that was closed, but it is this type of day to day problems as well as victories that a store owner could probably delve in better than the team leader for the entire project.

Finally, while KIWI is content in running this experiment on their own store and their own products, there is an important question to be answered on how these technologies are expanding laterally. REMA 1000 is using the existing concept and expanding it to its chicken processing plant in Orkdal, so it would be very interesting to see how the new concepts are suited to a different technology.

On the wood working side, it is of similar interest to see how the wood processing factories are managing the development of the new technologies. According to G1 the factory in Hobol is already generating enough product for the Green Advisor's needs and according to their specifications. That means they are producing wood products that have a smaller water content as well as putting into action the technology required to create the saw dust insulation material. The factory has actually shipped its first batch of fabric for the Island experiment so the next months to a year will present a good opportunity for research to be conducted over there as the building is taking shape and then goes through its first winter.

Similarly, the question of how these technologies are being implemented and for what reasons outside of Norway is of equal importance. Although they are not using fully integrated solutions like the Rema 1000 Kroppanmarka store, but there are stores using the latest CO_2 technologies in Italy, Switzerland, Germany and Romania. A more advanced version of this studies will look at the technologies implemented elsewhere in Europe, the actors and institutions, promoting that implementation, and the reasons behind them, as well as the challenges raised by different geographies and climate conditions.

10.Conclusion

The goal of this paper was to show how the transition to a sustainable socio-technical regime is taking place in Norway in an area that gets less visibility than the car manufacturing industry. The refrigeration industry in particular seems to have gone through the implementation of radical innovations, with the change from ozone damaging hydrofluorocarbons to the zero impact of CO_2. The change is still taking place and with the development of HFOs that might actually make a comeback. Still, most of the resources from industry leaders as well as the Norwegian government seem to be steering the discourse away from HFCs and HFOs and rather pushing it toward the alternatives, CO_2 and hydrocarbons. The reasons for this transition have to do with a more sustainable heating and cooling system as well as with the need to develop competitive technologies that will keep jobs from multiple sectors in Norway.

The transition, as it has been observed in this paper, is taking place on two different fronts. On the one there is REMA 1000 and its general propensity towards the pursuit of a radical innovation strategy. In terms of the multi-level perspective REMA 1000, whose headquarters are in Trondheim and is therefore in a landscape dominated by a history of academia and research conducted at NTNU and SINTEF. By developing its technology in close proximity to NTNU, REMA has the advantage of being able to call upon the technical expertise of the very people that are designing its systems. KIWI on the other hand is pursuing a more subdued strategy relying on incremental innovations in the CO_2 heat pump technology.

However, the switch to CO_2 driven heating pump is becoming the radical innovation that is organizing the heating and cooling in the supermarkets. Because CO_2 requires more energy to operate, the process of making its use feasible from an economic, but also from an ecologic use, requires the use of multiple technologies. Heat wells and handling the heating needs of adjacent buildings are one way in which existing stores are making use of the extra heat generated. However, that is not enough and there are two different paths that the two major store chains have taken. One is to invest heavily in the development of even newer and more high performing technologies the way REMA 1000 has been doing.

The alternative is what KIWI is doing and that is rely on traditional developers but seek new ways of reducing their footprint. They are relying on the more general landscape of the Norwegian tradition of massive wood buildings like the many wood churches. From KIWI's perspective the current technological breakthroughs that are on the horizon for the heating and cooling technologies would only improve their efficiency of the system by 20 per cent. Therefore, the bigger bet that they are making is that there are better reductions in their CO_2 footprint by looking at new building materials and techniques. Their reliance on wood has the double advantage of exploring local knowledge, traditions and materials and is a natural CO_2 capture system.

The building industry is just as preoccupied with the need to keep jobs in Norway and to have those jobs be taxed appropriately. There is also a need to reduce waste that also plays a big factor in the push for new technologies, which is common to both the refrigeration industry and the timber work industry. What is also common is a lack of public awareness regarding these technological advancements. Of course, there is also a significant debate to be had on the merits of using these technologies as example of innovations. Certainly, from the point of view of the technological innovation systems perspective there is serious doubt that can be cast on the idea that a new refrigerant or the use of wood chips as insulation can be seen as a radical innovation. The fact that these new technologies are a reversal of the effects these industries have had on the environment – which is to say encapsulating CO_2 as refrigerant rather the putting it back out into the atmosphere, or trapping it into building materials rather than putting out more toxic metals through the use of concrete – is itself the reason why a debate over the radical innovation status of these technologies needs to be had. It is not a knock down argument by any stretch of the imagination, but it does give pause for thought.

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Appendices

Appendix 1: Interview Guide

The interview with you will be a part of my master thesis which deals with the transition to sustainable technologies. More precisely, I am following a school of thought that monitors the way transitions are taking place and looks at the different types of institutions, networks, infrastructures and actors that need to come together so that what is currently a niche technology to be able to become the main technology used by the market. Your anonymity will by my top priority, I will delete the audio from our interview by the 1st of July 2019. During the interview we can stop at any moment, you can decide at any moment to pull out of the entire project, or you can choose to not approach any of the subjects that we will be talking of.

What type of technologies are you currently using?

What is the main technology being used today by the general public?

What are the advantages of the new tech?

What are the advantages of the old tech? / Why are the old technologies being used?

Who else is involved in implementing these technologies?

Who or what are the institutions promoting these technologies?

How are they doing it?

What are the biggest impediments in the mass adoption of these technologies?

If none, why are these technologies not being implemented?

Appendix 2 List of Interviewed Organizations/Firms

Organization/Firm	Position of Informant	Place, Year
NTNU	PhD / Researcher	Trondheim, 2018
NTNU	PhD / Researcher	Trondheim, 2018
Kiwi	Project Leader	Trondheim 2018
Meny	System Admin	Phone, 2019
Rema 1000	Project Leader	Phone 2020
ASKO	System Admin	Trondheim, 2019
Coop	System Admin	Trondheim, 2019
Statkraft	System Engineer	Trondheim, 2020
Ikea	System Maintenance	Trondheim, 2020

NTNU
Norwegian University of
Science and Technology