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# Managing step-change innovation in Hydro: Problem-solving under resource constraints

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# Preface

This paper is a master`s thesis written during the fall of 2015. It is my final work of the Master of Science program ‘Industrial Economics and Technology Management’ at the Norwegian University of Science and Technology (NTNU). My master`s specialization is ‘Change Management’, but as I have undertaken several courses in strategy and innovation, my project thesis and master`s thesis were both written under the specialization ‘Strategy and Innovation’.

This master`s thesis will serve as a delivery to the research project *Step-changes in mature production systems*. In this thesis, I study innovation in the process industry, and I present the concept of ‘step-change innovation’. More specifically, my paper investigates how step-change innovation projects are conducted in the case company of this thesis, Hydro, and I further present a conceptual model for managing step-change innovation projects in the process industry. What makes this thesis particularly interesting is that it explores innovation in the process industry, which is an area within the innovation literature in the need for further research.

These past months of writing my master`s thesis have without a doubt been a period of enriching learning experiences and insightful discoveries which I hope will be of value to Hydro and the research project. I have been given the opportunity to write my master`s thesis at Hydro`s headquarters in Oslo, and have thereby had a unique opportunity to conduct the data gathering process and discuss aspects of the thesis with knowledgeable people on the subject.

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# Executive Summary

The purpose of this thesis is to create the beginning of a theory of how to manage step-change innovation projects in process industries. Drawing on well-established definitions of different innovation types I present the concept of step-change innovation, which I define as: “The practical implementation of an idea, outside the current technological trajectory, leading to changes of the concepts in a production process”, and relate it to process innovation initiatives. I raise the following research questions:

- *RQ1: How are step-change innovation projects initiated in the process industry? Hereunder, what are the key issues or elements and how are they managed?*
- *RQ2: How are step-change innovation projects implemented in the process industry? Hereunder, what are the key issues or elements and how are they managed?*

Based on key lessons learned from three case studies within Hydro, I say something about what is best practice for managing step-change innovation in the process industry. Altogether 28 informants were interviewed, and although there are limitations to this study, I find the empirical evidence grounding the findings to be strong. The first step-change innovation project concerns the implementation of a new process technology in the wire rod cast house at Hydro’s plant in Karmøy. The second case is a step-change innovation project conducted in the Sunndal Carbon unit at Hydro’s plant in Sunndalsøra, and the third case investigated is a pilot project of the Adjustable Flexible Moulds (AFM) casting technology conducted in Høyanger.

Systematic problem-solving, external expertise and support of local management characterized the initiation of the step-change innovation projects. The possibilities for the production units to maintain the flexibility required for conducting ambiguous innovation projects were found to be constrained by daily tasks and continuous production within the unit. It was identified a pattern of new problems emerging when realigning the new technology with the existing machinery. The conceptual model for managing step-change innovation presented in this thesis, illustrates the advantages of having project managers on-site, devoting sufficient time to the project and working in a partnership with the production unit throughout the innovation process.

# Sammendrag

Målet med denne masteroppgaven er å legge grunnlaget for en teori om hvordan bedrifter i prosessindustrien kan legge til rette for såkalte ‘sprangforbedringer’. Basert på veletablerte definisjoner av forskjellige typer innovasjon, presenterer jeg begrepet ‘step-change innovation’ (sprangforbedringer), hvilket jeg definerer som: “Implementeringen av en idé, hvilket viker fra nåværende teknologisk bane, og som fører til endringer av konseptene i en produksjonsprosess”, og relaterer begrepet til prosessinnovasjon. I studien stiller jeg følgende forskningsspørsmål:

- *1: Hvordan initieres sprangforbedringer i prosessindustrien?  
Hva er hovedutfordringene og elementene, og hvordan håndteres disse?*
- *2: Hvordan implementeres sprangforbedringer i prosessindustrien?  
Hva er hovedutfordringene og elementene, og hvordan håndteres disse?*

Basert på funn fra tre case studier i Hydro, sier jeg noe om hva som er beste praksis for å lykkes med sprangforbedringer i prosessindustrien. Til sammen ble 28 informanter intervjuet, og på bakgrunn av dette anser jeg empirigrunnlaget som funnene i studien bygger på, som godt. Det første sprangforbedringsprosjektet omhandler implementeringen av en ny prosessteknologi i trådstøperiet på Hydros produksjonsfabrikk på Karmøy. Det andre er et prosjekt som ble gjennomført ved karbonanlegget på Hydros produksjonsfabrikk på Sunndalsøra, og det tredje prosjektet som studeres er et pilot prosjekt av en ny støpeteknologi gjennomført i Høyanger.

Systematisk problemløsning, ekstern ekspertise og støtte fra lokal ledelse var viktige elementer i initieringsfasen av disse prosjektene. Funnene viser at mulighetene produksjonsenhetene har til å opprettholde den fleksibiliteten som behøves ved gjennomføring av sprangforbedringsprosjekter preget av tvetydighet, blir begrenset av daglige oppgaver og kontinuerlig produksjon i enheten. Det ble identifisert et mønster hvor nye problemer oppstod andre steder i produksjonsprosessen da den nye teknologien skulle tilpasses det eksisterende systemet. Den konseptuelle modellen for gjennomføring av sprangforbedringsprosjekter som presenteres i denne oppgaven, illustrerer fordelene ved å ha tilstedeværende prosjektledere som setter av nok tid og ressurser til prosjektet, og som jobber i et partnerskap med produksjonsenheten gjennom hele innovasjonsprosessen.

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# 1 Introduction

## *1.1 “Step-changes in mature Production Systems”*

This master`s thesis will serve as a delivery to the research project *Step-changes in mature production systems*, a research project running from April 2014 and until September 2017. Participating companies are Hydro, Kongsberg Automotive, Volvo and Assa Abloy, with Hydro (Primary Metal) being the project owner. Further, the Norwegian University of Science and Technology, SINTEF Raufoss Manufacturing and Swerea IVF contribute to the project as research partners.

The research project`s purpose is to identify how to implement organizational structures and routines which will enable effective and quick ‘step-changes’ in production systems. It will be presented a definition of ‘step-change innovation’ later in this thesis, but as an introduction, the concept is associated with the implementation of technological or organizational innovations leading to changed work processes. Coordination and cooperation between technological or organizational expertise, typically organized in own departments, and the operations department is important to realize these innovations. It is acknowledged by the research participants that after a step-change has taken place, there is a need to again stabilize production in order to continue with the daily work with continuous improvement of operations.

The participating firms in the research project view their organization`s capabilities in frequently carrying out innovation projects in their production processes as more crucial than ever, due to globalization and an ever-increasing degree of automation in production processes. With increased complexity of work systems, there is a need to integrate the knowledge of operators, leaders and technology specialists, but the participants of the research project emphasize that it is still a need to identify concrete organizational structures and processes responding to this need. The research project`s RQ1 is: “*How can companies strengthen their step-change capability through improved collaboration between operations, R&D and other experts department within the organization?*”, and has as inspired the topic of this thesis.

## ***1.2 The increased importance of Innovation***

Due to increased competition and globalization, companies are making enhanced efforts to improve innovation performance in order to remain competitive (Trott, 2012). Environments are changing, and firms must constantly struggle to keep their alignment with external conditions in order to survive. Innovation has long been argued to be the engine of growth (Trott, 2012; Blanchard, Amighini, & Giavazzi, 2013), and such activities are crucial for a firm's ability to adapt and change.

In order to innovate, a creative idea must be combined with resources and expertise that make it possible to convert the creative ideas into something useful (Schilling, 2013). Innovation is not a single event, but a series of activities linked to each other. One definition of innovation is given by Schilling (2013): "The practical implementation of an idea into a new device or process" (p. 18). Trott (2012), however, defines it as a management process: "Innovation is the management of all the activities involved in the process of idea generation, technology development, manufacturing and marketing of a new (or improved) product or manufacturing process or equipment" (p.15). A proper understanding of what innovation involves, affects the company's capability to successfully organize for it.

When seeking to gain an increased understanding of innovation, it is essential to investigate various dimensions of the concept. One dimension represents *product innovation*, taking place in the outputs of an organization; its goods and services. Another is *process innovation*, which relates to the way an organization conducts its business (Schilling, 2013). These types of innovations often come in tandem, either because a product innovation enables development of a process innovation, or vice versa (Schilling, 2013). Further, innovations are also characterized as either radical or incremental, depending on the "newness" of the innovation. *Radical innovations* represent significant leaps in technology development (D. J. Kelley, O'Connor, Neck, & Peters, 2011), whereas *incremental innovations* "... makes a relatively minor change from existing practices" (Schilling, 2013, p. 46). The concept of *step-change innovation* I will present later, relates to process innovation activities with newness somewhere in between incremental and radical innovation.

### ***1.3 Research Questions***

The purpose of this study is to explore aspects of process innovation projects in the process industry, with the goal of establishing a first-hand platform of knowledge for further research. In the academic literature today, product development, and not process development, has been the focus of researchers (Lager, 2002). Further, innovation in process industries is a topic currently lacking sufficient research (Frishammar, Blanco & Lager, 2013a). In fact, researchers found the topic of innovation in process industries to be so unexplored that the journal of *R&D Management* in 2013 published a special issue solely containing articles aimed at increasing the understanding of innovation in process industries (Frishammar et al., 2013a). I conducted literature searches prior to deciding on the research topic for this thesis, and as I had sparse results from my searches on elements affecting the success of process innovation projects in process industry, I therefore concluded this was a field in the need for further exploration. Further, as the implementation phase of an innovation initiative has been given far less attention than the idea generation phase in the innovation literature (Govindarajan & Trimble, 2010a), I address the following research questions in this thesis:

- *RQ1: How are step-change innovation projects initiated in the process industry? Hereunder, what are the key issues or elements and how are they managed?*
- *RQ2: How are step-change innovation projects implemented in the process industry? Hereunder, what are the key issues or elements and how are they managed?*

My goal is to develop a conceptual model for managing step-change innovation in the process industry. Based on key lessons learned from the three case studies, I will say something about what is best practice for step-change innovation in the process industry.

### ***1.4 Relevance of Thesis***

I consider it to be important to provide a fresh perspective to the area of how firms in the process industries can organize for, and implement, new technologies to optimize their production processes. Anand, Schilling, Tatikonda and Ward (2009) found that all companies they investigated had initiatives focusing on continuous improvement, lean management and Six Sigma. However, none of the firms studied had a framework in place to address routines for process innovation with a higher degree of newness. This is something this study

investigates. As the pace of business environments is increasing, one could argue that organizations today in fact compete on the ability to continuously improve their processes (Anand et al., 2009), focusing on their capability to produce efficiently and flexibly. The interaction between innovation, technology and organizing is a classical issue, becoming increasingly more important by the pressing demands on companies in all industries for higher speed in innovating. Due to globalization and sustainability challenges, R&D and innovation in process industries are a major stake for future success. *On the one hand*, globalization leads to more intense competition and lower prices on produced products, while the increased focus on the environment puts production facilities under an enormous pressure for lowering emissions and effective production. *On the other hand*, globalization also leads to an expanded market for sales, new customers, new contractors and almost an infinite possibility to get your hands on the latest technology developed, while the ever increasing sustainability focus forces companies to think creatively and new, which again opens up new windows of opportunities. No matter one's view on globalization and the increased focus on sustainability, one must acknowledge that for companies in the process industries, this ultimately leads to an increased focus on cost-cutting, effective production, and more frequent implementation of new technologies in the production processes. It is my opinion that the general literature stream of R&D and innovation management does not cover the challenges or characteristics of how companies should best organize to face these challenges and opportunities in a satisfying way. My thesis is therefore interesting for managers in process industries who seek to achieve more frequent step-change innovation, while continuing to develop their production system with incremental innovations and fine-tuning in parallel.

## ***1.5 Structure of Thesis***

The thesis is organized the following way: I will start with a presentation of relevant theory in chapter two, three and four. Current theory on innovation culture, innovation in the process industry, and different classifications of innovation will be presented. Then, I present a definition of 'step-change innovation', and further elaborate on challenges related to successfully carrying out these innovations in the process industry. The theory part of this thesis will end with a presentation of suggestions on how to organize for innovative activities. Following this, I will go through the methodology used in this study in chapter five and present the case company in chapter six. A within case analysis for each of the innovation projects will then follow, before the findings are summarized in a cross-case comparison.

# 2 Innovation Culture

## *2.1 Definition*

Innovation is a broad term, covering several aspects of business and everyday life. Several management tools and best practice guidelines are today available for managers to assist organizations succeed in the pursuit of innovation. However, not only tools, resources and processes define how innovative a company is. In order to grasp the process of innovation, one must understand how innovation relates to organizational culture. The importance of organizational culture for innovation is growing in awareness among researchers (Jassawalla & Sashittal, 2002; Rao & Weintraub, 2013). Claver, Llopis, Garcia, and Molina (1998) emphasize that although there is a great need for technical preparation in material, financial and human resources for successful technological innovation to take place, the corporate culture is of great importance and should not be overlooked by managers. A clear definition of corporate culture is given by Claver, Llopis, Garcia, and Molina (1998):

We define corporate culture as a set of values, symbols and rituals shared by the members of a certain firm, describing the way things are done within an organization when solving internal managerial problems, together with those related to customers, suppliers and environment (p.61).

Authors have argued that organizational culture is key to managing innovation (Khazanchi, Lewis, & Boyer, 2007). “In other words, the hardware of technological innovation requires the software of a corporate culture which is aimed at innovation” (Claver et al., 1998, p. 64). When discussing technological innovation, as an example, the culture can play an important role by stimulating the process of generating new ideas and applying them. The human factor in technological innovation, and the need for people’s acceptance of change, is of great importance (Claver et al., 1998). As changes are caused by decisions people make, fostering an innovation-supportive culture focusing on team-work and having creative employees which are not afraid of taking risks must be emphasized (Jassawalla & Sashittal, 2002), as well as organizational members should be comfortable with admitting mistakes and pursuing own ideas (Edmondson, 2004; Rao & Weintraub, 2013).



## 2.2 An Innovative Culture

Rao and Weintraub (2013) created a framework describing building blocks for an innovative company culture, and present six building blocks which they argue are the essence of an innovative culture. The building blocks cover different aspects on an organizational culture for innovation; resources; processes; values; climate; behavior; and success (Rao & Weintraub, 2013). The six building blocks are further composed of three factors (18 in all), and each of those factors consist of three underlying elements (Rao & Weintraub, 2013).

### 2.2.1 Resources

Resources can be grouped into tangible and intangible assets (Bessant, Caffyn, & Gallagher, 2001). Resources are often associated with finances, buildings and other assets that can be measured to a finite value; all of which comprise the tangible assets of a firm. Intangible assets, on the other hand, are made up of *knowledge assets* - what the organization knows - and *behavioral patterns* - the way the organization operates (Bessant et al., 2001).



Figure 1: An Innovative Company Culture

*People* have been argued to be the most important resource in a company, as these have a powerful impact on the organization's values and climate (Rao & Weintraub, 2013). The innovative capability of a company can be substantially enhanced by employees with the desired characteristics and behaviors. In particular, "innovation champions" can make a great difference. These champions play several roles in the innovation process, such as: providing of autonomy to employees; organizational support for the innovation; establishment of mechanisms for consensus decisions on innovations; and use of informal methods to persuade other members of the organization (Shane, 1994). Various *systems* also play an important role in the pursuit of innovation. Successful companies often possess tools that ease the collaboration in innovation efforts. Further, the organization must *allocate time and resources to innovation projects* such that people are able to pursue new opportunities (Rao &

Weintraub, 2013). The organization should have finances dedicated solely to the pursuit of new opportunities (Rao & Weintraub, 2013), such as funds allocated specifically for R&D projects. Dedicating enough resources to basic research is also important, as this can enhance the organization's absorptive capacity (Cohen & Levinthal, 1990).

Christensen and Overdorf (2000) argue that it is in the startup stages of an organization that having the right resources is of the greatest importance. However, as the organization matures, the organization's capabilities shift more towards processes and values. Thus, even though having the right resources are critical for any organization, a mature organization can have processes and values so powerful that it almost does not matter which people get assigned to which project teams (Christensen & Overdorf, 2000). This leads us to the second building block of an innovative culture, - the organization's *processes*.

### **2.2.2 Processes**

Christensen and Overdorf (2000) define processes as “the patterns of interaction, coordination, communication and decision making employees use to transform resources into products and services of greater worth” (p.3), and further explain that processes can be understood as the routes innovations follow as they are developed. This building block is aimed at capturing the extent to which an organization successfully generates innovative ideas, filter and prioritize them, as well as addressing other dimensions of an organization's innovation processes, such as prototyping, flexibility and time to launch (Rao & Weintraub, 2013). Johnson, Christensen, and Kagermann (2008) emphasize that all successful companies have operational and managerial processes which allow them to continuously deliver value to customers and increase scale. Christensen and Overdorf (2000) highlight that one of the challenges for management today is that processes are poorly designed to tackle different tasks, as they usually are set up in such a way which allows employees to perform tasks in a consistent manner. The very capabilities that make an organization effective can therefore also define its disabilities, and affect what types of change the organization is capable or incapable of handling (Christensen & Overdorf, 2000). When seeking to improve its processes for innovation, it is important, however, that companies focus attention on its own unique challenges. Hansen and Birkinshaw (2007) emphasize that a firm needs to pinpoint its weakest links, and then strengthen them, as importing the latest best practices could end up further worsening an already broken innovation process (Hansen & Birkinshaw, 2007).

When discussing processes for new product development, several models have been created as a response to the increased pressure to reduce the cycle time and product “hit rate”. Cooper (1990) introduces the concept of a stage-gate system, which is both a conceptual, and an operational model for moving a new product from idea to launch. It has been argued, however, that stage-gate models do not handle ambiguity very well, and the role of ambiguity in the new product development process (Brun, Saetre, & Gjelsvik, 2009), thereby limiting their applicability. In order to acquire or seize opportunities, a tolerance of, and an ability to handle ambiguity, is required (Sætre & Brun, 2013). From this, one can understand that managing processes for innovation is a critical, but difficult task.

### 2.2.3 *Success*

According to Rao and Weintraub (2013), success can be captured at three levels: *external*, *enterprise* and *individual*. External recognition is linked to whether or not a company is being recognized as innovative by its competitors and customers, and whether its innovation efforts has led the company to better financial performance than others in the industry (Rao & Weintraub, 2013). One may wonder why the company’s external reputation is important? One aspect could be when pursuing business model innovation, which can be an important source of innovation (Amit & Zott, 2012; Chesbrough, 2010; Johnson et al., 2008; Teece, 2010). In such situations the company may be forced to look beyond its traditional sets of partners and customers, and find new ones (Amit & Zott, 2012). Success is also captured on the enterprise level; *is innovation treated as a long term strategy?* According to Schilling (2013), if a firm’s success rate is to be improved, a well-crafted strategy is required. Building on the resource-based view of the company, she further emphasizes the importance of aligning the organization’s innovation projects with its resources and objectives. On the individual level, employees should be satisfied with their participation in innovation efforts. Amabile and Kramer (2011) found that the most common event triggering a “best day” was progress accomplished by either themselves or their team. To increase individual motivation, managers should therefore focus on supporting employees to help them see their everyday progress, even their small wins.

Diving further down into the success block does raise some interesting questions, such as what characteristics does a successful organization have? Tjosvold (1998) interviewed executives in forty successful companies in the search for the key to developing innovative organizations, and found an indication that effective *employee involvement* was a critical mediating mechanism between people-oriented values and firm performance. However, the

generalizability of his results was limited due to operations and sample. Levinthal and March (1993) argue that if an organization has achieved success and improved performance by developing capabilities and knowledge in one area, the organization's incentive for learning new technologies is actually reduced. This is an interesting aspect to keep in mind in relations to the innovative capabilities of an organization, and in particular for the process industry.

#### **2.2.4 Values**

A company's values should be supported in tangible ways as this reflects the company's priorities. Time and money spent by the company's management should show that the company value innovative behavior and creativity (Rao & Weintraub, 2013). It is not enough that the values are simply *communicated* by senior management; they need to be demonstrated by driving decisions made by the managers (Rao & Weintraub, 2013). The values of a company are demonstrated by the way organizational members behave, and therefore also affect what an organization can and cannot do as the values have implications for the standards by which employees set their prioritizations (Christensen & Overdorf, 2000). Prioritization decisions in a company are made by employees at every level, and employees throughout the organization should be trained to make independent decisions about priorities which are consistent with the strategic direction of the company (Christensen & Overdorf, 2000). Khazanchi, Lewis, and Boyer (2007) introduce the concept of value profiles, which can be understood as a cohesive set of organizational values which orient its members and guide their expectations, decisions and actions. On the one side, a company can have a flexibility profile where creativity, change and empowerment are likely to be focused on by all its members. On the other side, a company might also have a control value profile, encouraging efficiency, productivity and stability. The value profile a company chooses will affect its innovative capabilities. Thus, if a company seeks a flexibility value profile in order to increase the creative behavior of their members, management needs to provide sufficient resources for people to engage in creative behavior (Amabile, Conti, Coon, Lazenby, & Herron, 1996).

#### **2.2.5 Behaviors**

Behaviors, in general, can be understood as the way one conducts oneself, and in the context of this thesis, it is understood as the way people act in the cause of innovation (Rao & Weintraub, 2013). The behavior of leaders is particularly important for the company culture and are intended to result in desired behaviors from subordinates in the organization. Research has shown that the way leaders behave can greatly affect the employee's individual

innovative behavior (de Jong & Den Hartog, 2007). Drawing on Farr and Ford (1990), de Jong and Den Hartog (2007) define innovative behavior as “behavior directed towards the initiation and application (within a work role, group or organization) of new and useful ideas, processes, products or procedures” (p. 43). In their study, innovative role-modelling, support for innovation, recognition, and organizing feedback, were some of the leader behaviors they found to be connected to individual innovative behaviors of employees. Further, Feldman (2003) argues that supervisors must behave in a way which implies that the ways they are asking subordinates to work as valued enough by them (Feldman, 2003). Hence, innovative behaviors of supervisors will most likely be observed and copied by employees.

### ***2.2.6 Climate***

According to Rao and Weintraub (2013), “an innovative climate cultivates engagement and enthusiasm, challenges people to take risks within a safe environment, fosters learning and encourages independent thinking” (p. 30), and is considered crucial for organizational members to engage in innovative activities. It is important that climate is not confused with culture. Baer and Frese (2003) explain that “... culture can most accurately be understood as existing at a higher level of abstraction than climate” (p. 48), and that climate is often linked to the activities that produce visible and tangible outcomes. It is not hard to see why the climate plays a key role when participating in innovative activities, as employees need to; feel safe enough to speak their minds and offering different points of view; engage in debates without feeling threatened or insecure; and trust their colleagues enough take risks and daring to participate actively when working in teams. When pursuing innovations, learning from experiments and failures is a part of everyday life. If people face the potential for threat or embarrassment they tend to act in ways that inhibit learning (Edmondson, 1999), which in turn inhibits the generation of novel ideas. Further, trust is an essential part of work climate, and involve perceptions of risk or vulnerability (Edmondson, 2004), thereby greatly affecting the risks employees are willing to take when engaging in work activities. However, achieving an innovative climate where creative ideas flourish and people actually engage in risk-taking activities is not possible without motivated people. Creativity will be optimized when people are primarily intrinsically motivated, which means they are motivated by the interest, enjoyment, and challenge of the work itself (Amabile et al., 1996). Focusing on creating a climate for innovation is therefore a critical management task for companies. Having presented innovation culture, I will now present theory on innovation in process industries.

# 3 Innovation in Process Industries

## *3.1 Definition and Characteristics*

The process industries span multiple sectors including petrochemicals and chemicals, food and beverage, mining and metal, mineral and material, generic pharmaceuticals, forest and steel (Lager, 2011). A definition will provide a frame of reference for this study:

Process industry is production industry using (raw) materials to manufacture non-assembled products in a production process where the (raw) materials are processed in a production plant where different unit operations often take place in a fluid form and the different processes are connected in a continuous flow.

(Lager, 2002, p. 88)

A key feature of process industries is that both output and input are often materials or ingredients, and not components, and they are often commodity producers (Lager & Storm, 2013). Further, process industries are asset intensive and usually characterized by having large fixed items of capital equipment (Aylen, 2013). The facilities tend to be distributed over a few physical locations (Lager, 2011), and for the most part, as a result of high investment costs, process plant technology has a long lifetime once built (Aylen, 2013). The characteristics of the production processes differ from other industries. The production structures in process industries are often very long, and usually both the supply and value chains are complex and interconnected (Lager, 2011). As large parts of the value chains often affect each other, product and process development within such firms often take place in collaboration with suppliers and other component manufacturers. This can be both manufacturers of process equipment, as well as suppliers of raw materials (Lager, 2002), all of which affect daily operations.

Considering the key features of process industries presented above, one can easily understand that how innovation activities are conducted in process industries differ from other manufacturing industries. Lager (2011) states that the largest difference in how development activities conducted in the process industries differs from other manufacturing industries, is the strong relationship between product development and process development. He

emphasizes that in process industries one cannot develop new products without a proper understanding of the production process technology, and vice versa. He summarizes the key features of research and development work in the process industries as follows:

- Development work is done in a laboratory/pilot plant / production plant environment and not in a design office.
- Constructing prototypes is not an intermediate development stage in product development but is replaced by test runs in pilot plants or full production, manufacturing batches of new products for customers and verifying process conditions.
- Customers are often industrial business-to-business or B2B on long supply chains, before finally reaching the end user business-to-consumer or B2C.
- Process development often takes place in collaboration with manufacturers of process equipment and suppliers of raw materials and reagents.
- Changes in the company`s portfolio of products and product varieties are often very complex, since the company`s production structures are long internal interconnected production chains.
- Final quality of products and intermediate product properties are related to available raw material properties.

(Lager, 2011, p. xii)

There are differences in the innovative activities undertaken in process industries, and each of them has distinct prerequisites for them to happen. I will continue with presenting the characteristics of incremental and radical innovation activities in process industries

### ***3.2 Incremental and radical Innovation in Process Industries***

Minor changes can play an important role in developing processes, and the need for continuous improvements in both products and processes is widely recognized (Bessant et al., 2001). Incremental innovation builds on a firm`s current abilities and is characterized by small changes in technological trajectory (Benner & Tushman, 2003). Over the years, initiatives such as lean production, Six Sigma and TQM have been extensively introduced in manufacturing organizations. Such initiatives are undertaken in order to improve efficiency of manufacturing and decrease variation in the production processes. What these process

management tools all have in common is that they seek to build capabilities for continuously innovate incrementally in operations and continuously improve production processes (Bessant et al., 2001). The ultimate goal is to achieve behaviors for continuous improvement. Continuous improvement (CI) is defined as “a systematic effort to seek out and apply new ways of doing work i.e. actively and repeatedly making process improvements” (Anand et al., 2009, p. 444), and it has been argued that such initiatives enable organizations to improve performance in a quicker pace (Bessant et al., 2001).

Process management activities are related measuring, improving and rationalizing organizational processes. It involves not only rationalizing individual work processes, but also streamlining the handoffs between the processes. Proponents of process management argue that these activities lead to numerous organizational benefits (Bessant et al., 2001; Anand et al., 2009), such as increased yields, less rework and waste, cost reductions and faster delivery times. Opponents on the other hand, show to examples of companies having implemented such initiatives, and later suffered subsequent financial loss. As an explanation, Benner & Tushman (2003) state that by removing variation-increasing activities you remove an organization`s ability to adapt outside its established technological trajectories and its ability to innovate. Today there is a high failure rate for CI programs. It has been suggested that the reason for this is due to a lack of understanding of the behavioral dimension (Bessant et al., 2001). Another explanation given for why these programs fail to deliver the desired results is that the overall organizational context is not appropriate (Anand et al., 2009).

Radical innovation is characterized by fundamentally changing the technological trajectory in an organization, and is often associated with experimentation. Such efforts are exploratory, and therefore require new competence and knowledge (Benner & Tushman, 2003). Such innovation efforts are often undertaken with the aim of meeting the needs of new emergent customers or markets (Benner & Tushman, 2003). Occasionally, there are severe discontinuous technical changes in process industries. Such innovative activities call for new plant items, and scrapping of old technology (Aylen, 2013). In process industries, development projects with high degree of newness are usually carried out in pilot plants and span over several years (Lager, 2011). Radical technological development projects in process industries require substantial investments, but they are necessary. Such efforts have been proven to not only contribute to cost efficiency and production scaling, but also to new product performance through improved product quality by increasing the reliability of production processes (Bauer & Leker, 2013).



### ***3.3 Process Innovation in Process Industries***

#### ***3.3.1 Classifications of Innovations in Process Industries***

It was earlier presented two dimensions of the innovation concept: process innovation and product innovation. Making a distinction between process and product development in process industry is important to avoid confusion (Lager, 2002). *Process development* is defined as ‘development driven by internal production objectives’ (Lager, 2002, p. 88). Such targets may be reduction of production costs, higher production volumes or a more environment-friendly production process. *Product development*, on the other hand, can be defined as ‘development driven by a desire to improve the properties and performance of finished products, even though the improvements may be achieved by modification of the process’ (Lager, 2002, p. 88). Product quality and property is thus the focus. Based on the characteristics of process industries, Lager (2011) states that the two are dimensions are easily confused with each other. He notes that in process industries, product development and process development are very closely related, and affect one another: “A process development project can thus give opportunities for product developments, just as the development of new products can sometimes be combined with process development and cost reduction in the production process” (p. 43). The reader should be informed that in this study, the focus is on innovation in the production processes, *process innovation*. Frishammar, Lichtenthaler and Richtnèr (2013b), as Lager (2002), also discuss process development. They define it as “deliberate and systemic development related to production objectives, implying the introduction of new elements into the production process with the purpose of creating or improving methods of production”(p. 215). Thus, it centers on improving *how* manufacturing work is done. Frishammar, Lichtenthaler and Richtnèr (2013b) distinguish between two types of process development: *process improvement* and *process innovation*. According to them, process improvement typically refers to continuous improvement of existing processes with the aim of achieving improved efficiency. Thus, process improvement represents fine-tuning of processes. *Process innovation* on the other hand, presupposes all-encompassing changes to the manufacturing processes. This type of process development can be linked to more radical innovation efforts. Frishammar, Lichtenthaler and Richtnèr (2013b) do state, however, that these categories of process development are a matter of a continuum, rather than clear-cut categories. In his article, Lager (2002) developed a system for the classification of process development initiatives in process industry. The matrix is presented below:

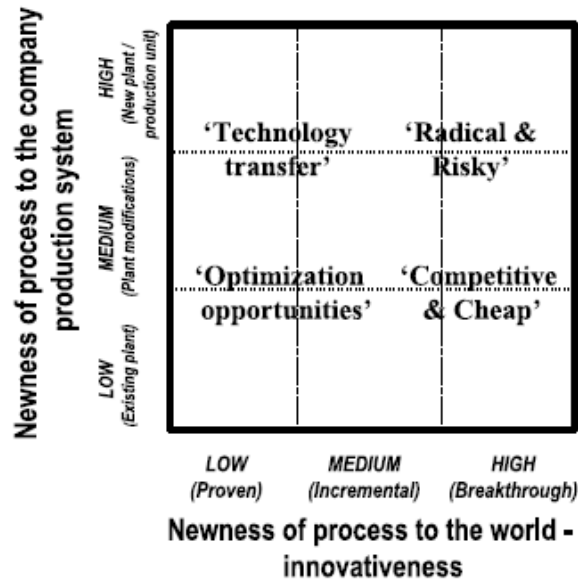


Figure 2: Four elements of the process matrix and their denominations

The two dimensions of which the matrix is built up are *newness of the process technology to the world*, and *newness of the process technology to the company production system*. Newness of the process technology to the world, as a dimension, refers to how well known or proven the process technology is outside the company. *Newness of the process technology to the company production system*, on the other hand, is a measure of the extent to which the introduction of a new process will affect the existing plant, or unit, in terms of investment in new equipment. The dimensions have three degrees of newness to them, ranging from low to medium, and high.

<b>Element:</b>	<b>Description:</b>
<b>Optimization opportunities</b>	Refers to the use of proven or incrementally improved process technology in an existing plant environment. This type of process improvement is not the development of a new process, but the refinement and optimization of an existing one.
<b>Technology transfer</b>	Applying an already proven technology in part, or as a whole, in the company production plant. Then newness of the technology might be low, but the newness to the company production system might be high.
<b>Radical and risky</b>	This is an area of the matrix there is medium to high newness in both dimensions. Process technology in this area is of a kind that can make old plants production units obsolete. Such efforts has a high risk.
<b>Competitive and cheap</b>	This describes developments in the processes where the degree of newness to the world is medium or high, but the technology itself needs only moderate plant investments.

Table 1: Description of the process matrix

The four areas in the matrix classify process development projects into four categories, as presented in the table above. Lager (2002) emphasizes that a distinct classification is tricky, as there is always a chance the innovations require both old and new technology. It should be noted, though, that I consider the labelling of these axes as inconsistent with the existing innovation literature. It seems Lager (2002) is confusing innovation with invention. The Y-axis is as it should be. However, the X-axis is more related to the invention of an idea, and not innovation. Whereas invention is the creation of a new idea, the definition of innovation is broader and includes the process of developing and implementing a new idea. The idea may be a recombination of old ideas, a formula or a unique approach. It matters little, whether or not an idea is ‘objectively’ new as measured by the lapse of time since its first use or discovery. If the idea is new to the individual, it is an innovation. I refer to the definitions on innovation provided by Schilling (2013) and Trott (2012), presented earlier in this thesis.

### **3.3.2 The Phenomenon of Stretch**

With the intent to increase the understanding of innovation in process industries, Aylen (2013) introduces the concept of *stretch*. Aylen defines stretch as: “the continual modification of a plant, system or service beyond its initial design specification, with the aim of increasing capacity, but also to increase product range and quality and use new input” (2013, p. 272). Stretch as a phenomenon, helps one understand how a plant in process industries, initially built to produce a certain output, some years later produce outputs far beyond its initial design capacity, and has the ability to produce a wider range of products than originally envisaged (Aylen, 2013). Stretch is considered to be an evolutionary process where a factory evolves through *solving a sequence of problems*. Aylen (2013) states that, “Innovation is driven by problem solving” (p. 283), meaning that changes in the production processes are often initiated by search for solutions to practical operating problems. This is consistent with what Cyert and March (1963) emphasized, when they argued that once performance falls below aspiration levels, search is initiated.

At first it may sound like stretch only refers to incremental fine-tuning of the process and equipment, but the taxonomy of stretch presented by Aylen (2013) covers different process innovation efforts. It is based on a five-way classification, which can be found attached in the Appendix of this thesis with detailed explanations. What is evident from the five dimensions presented by Aylen (2013), and the process innovation efforts presented above, is that they all cover different degrees of “newness”. For example the second notion of ‘stretch’, *addition of novel equipment and reconstruction*, covers both plant improvement by *adding of ‘Bolt-on-*

*goodies*’ and *reconstruction of existing plant*. ‘Bolt-on-goodies’ are explained as incremental process improvement, and are incremental process innovations. On the contrary, reconstruction of existing plant is a quite expensive and drastic way of plant improvement. Thereby, the taxonomy of stretch covers several types of process innovation activities, ranging from process development efforts with low degree of newness, to the more radical kind. The innovative efforts presented in the taxonomy of stretch must be carefully managed, as there must be a balance between exploratory and exploitative innovation activities in an innovation portfolio (Bauer & Leker, 2013; March, 1991; Benner & Tushman, 2003).

The current literature on process innovation initiatives in process industries clearly shows that there are varying degrees of innovativeness in the projects undertaken, ranging from small and incremental efforts to radical innovation projects including extensive research and investments. However, there seems to be lacking a coherent way to classify process development projects in process industries. This is why I will present a new and broader dimension of the innovation concept, aimed at covering a range of process innovation projects undertaken in process industries. The notion of process development (Frishammar et al., 2013b), stretch (Aylen, 2013) and the classification of process development projects presented by Lager (2002), all include descriptions of some innovations which are not minor improvements to the existing production system, nor the radical type. Lager and Hörte (2002) also divided between different types of process development activities based on their degree of “newness”. They were trying to improve their insight of what types of behaviors and tools benefit successful process development projects, and subsequently divided the projects into the categories *process improvement*, *incremental development* and *process innovation*. Again, an example of another way to classify process innovation projects in the process industries.

# 4 Step-change Innovation

## 4.1 Definition

To better understand process innovation in the process industry, I will present a definition of ‘step-change innovation’. The traditional literature on innovation has separated between incremental and radical innovation. Drawing on Nelson and Winter (1982), and several other researchers, Henderson and Clark (1990) define incremental innovation the following way: “Incremental innovation introduces relatively minor changes to the existing product, exploits the potential of the established design, and often reinforces the dominance of established firms” (p. 9). Drawing on Dosi (1982), and Green, Gavin and Smith (1995), Benner and Tushman (2003) explain that radical innovation, “Fundamentally changes the technological trajectory and associated organizational competencies” (p. 243). Clearly, radical innovations require more experimenting and iterative problem solving, than incremental innovations. However, when exactly does an innovation cross the line from being an incremental or radical innovation? Is there not a situation in between these two extremes where the innovation has characteristics from both kinds? Henderson and Clark (1990) argued that the traditional characterization of innovation was not sufficient, and thus presented the concepts of ‘modular innovation and ‘architectural innovation’. They define modular innovation as: “Innovation that changes only the core design concepts of a technology” (1990, p. 12), and architectural innovation as: “Innovation that changes a product’s architecture but leaves the components, and the core design concepts that they embody, unchanged” (1990, p. 12). However, these definitions describe types of *product innovations*, and are therefore not directly applicable for my research on process innovation. Drawing on the definitions above, and the definitions on innovation presented earlier, I define step-change innovation as: “The practical implementation of an idea, outside the current technological trajectory, leading to changes of the concepts in a production process”, and relate the term to process innovation activities. It covers process innovations with a higher degree of innovativeness than incremental innovation activities, yet not radical. Hence, the concept of step-change innovation covers a range of innovation in between the incremental process innovation and radical process innovation. According to my definition, step-change innovations are more extensive than continuous improvement, and will require integration of specialist knowledge which is typically not located in ongoing operation, but rather staff functions or R&D-departments.

They will also demand increased organizational flexibility when implemented, as these process innovations will affect the existing system. Further, such innovation efforts involve multiple departments, and the projects consist of distinct phases.

## ***4.2 How to increase the frequency of step-change innovation***

If one is to increase the frequency of step-change innovations in a production process, one must somehow develop some kind of routine for such projects. An organizational routine can be defined as, “a repetitive, recognizable pattern of interdependent actions, involving multiple actors” (Feldman & Pentland, 2003, p. 96), and are the engine for the work that firms, organizations and markets accomplish. Routines have traditionally been related to stability and inertia, and are a key component in organizational learning (March, 1991), where they play the role of memory (Huber, 1991). If industrial companies develop routines for continuous improvements and incremental innovation, how do you combine these routines with routines for conducting larger innovative projects? Aylen (2013) presents what he calls the ‘Stretch paradox’: The operations in process manufacturing systems tend to be characterized by formal routines and hierarchical structures, where the focus is on variance reduction (Aylen, 2013). In contrast, innovation activities with higher degrees of newness require creativity, project management skills and entrepreneurial implementation. Thus, Aylen (2013) further presents the dilemma: “How do you stretch a process plant through application of novel equipment, untested operating procedures and unfamiliar products when steady operation is at a premium?”(p. 283). This dilemma relates to creating parallel, and different, routines within the organization, and touches upon the same challenges presented by Benner and Tushman (2003). Benner and Tushman (2003) argue that process management activities are inconsistent with all but incremental innovation. They claim that the focus on variation reduction and search for incremental improvements in routines, will lead to increased incremental innovation, exploiting existing capabilities. It has previously been argued that search and focus on incremental innovation ultimately will lead to a reduction in exploratory activities and learning outside the existing technological trajectory (March, 1991). If step-change innovation, after my definition, lies in between incremental and radical innovation, conducting such activities will suffer under the challenges related to the stretch paradox.

Aylen (2013) presents two possible solutions to the paradox of stretch.

- Firstly, he claims that promotion of stretch requires re-engineering and cross-functional teams. This approach supposedly helps solve frustration of employees stuck working in specialized roles on routine and repetitive tasks.
- Secondly, planning. He argues that process innovation needs to be planned in the same way as product innovation, as process and product innovation are intertwined with new process steps generating new products, and vice versa.

### 4.3 Organizing for step-change Innovation

The first solution to the paradox of stretch can be found in how you organize the innovation initiative. To ensure everyone contribute with their ideas of how to do things better, and the active engagement of employees in different functions, the processes of how you coordinate people`s efforts play a crucial role (Adler, 2011). In order to succeed with an innovative initiative, Govindarajan and Trimble (2010a; 2010b) describe an organizational model they argue can be adapted to incremental, radical, process and product innovation (from my definition; therefore also step-change innovations). They propose a *Project Team* consisting of a partnership between a *Dedicated Team* and *Shared Staff*. The Dedicated Team is dedicated to the innovation initiative full time, whereas the Shared Staff supports the innovation initiative part time. The Shared Staff is a part of what is referred to as the Performance Engine, which handles the daily operations. The model is presented below:

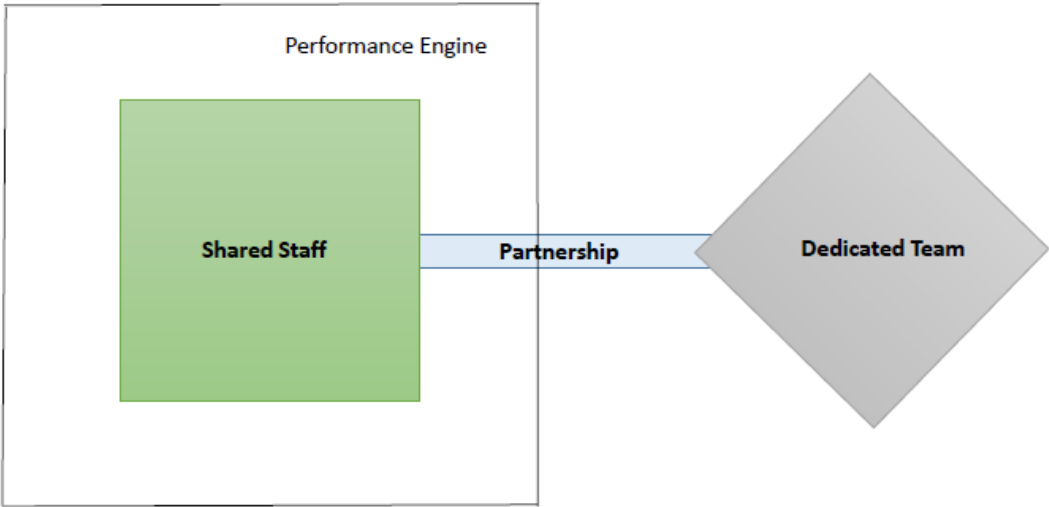


Figure 3: Organizing an innovation initiative

In this partnership, they argue that there needs to be a clear division of labor. Each partner's responsibilities needs to be defined early. Govindarajan and Trimble (2010a) emphasize that it is important not to assign the Performance Engine with more work than it can handle while still maintaining excellence in ongoing operations. Govindarajan and Trimble (2010a) further explain that one of the most frequent problems is to fill the Dedicated Team entirely with insiders, as they are resources that are cheap and easy to find. However, they argue that in order to build an effective team, existing work relationships needs to be broken down, and suggest using outsiders in the Dedicated Teams. They state that outsiders usually challenge assumptions, as their biases are rooted in experiences from other companies (Govindarajan and Trimble, 2010a), and that this benefits the initiative. Once the Dedicated Team is put up and the Shared Staff has been appointed, the next question might be related to how close the Dedicated Team should work with the Performance Engine and the Shared Staff. The cooperation and coordination needed throughout the project might be different in the different stages. According to Paul Adler (1995), the more the current project deviates from previous experiences, the more interaction between departments is required. Further, he presents the term 'analyzability', which he defines as "the difficulty of the search for an acceptable solution to the given fit problem" (1995, p. 158). Adler (1995) states that low analyzability calls for a greater effort for coordination in the later phases due to the difficulty low analyzability creates in knowing how to cope with the issues in the earlier phases. This implies that when departments work together on innovations, complex projects might require more coordination in later stages than early stages, as it might be difficult to predict the challenges that might occur.

In addition to suitable organizational structures, one understands that the solutions to the stretch paradox require extra resources, or *slack*. Nohria and Gulati (1996) define slack as "the pool of resources in an organization that is in excess of the minimum necessary to produce a given level of organizational output" (1996, p. 1246). They include both resources such as redundant employees, unused capacity, and unnecessary capital expenditures. Sufficient resources are necessary in order to coordinate employees, train the employees, handle communication and follow-up throughout an innovation initiative. Nohria and Gulati (1996) argue that, "too little slack is inimical to innovation because it discourages any kind of experimentation whose success is uncertain" (p. 1260). An example of consequences of having too little slack can be found in the article of Inamizu, Fukuzawa, Fujimoto, Shintaku and Suzuki (2014). They found that leaders in Japanese automobile assembly plants were



often forced to do the line work of the operators due to shortage of people. As a result, this mode prioritizes the on-line activities over the off-line activities in order to overcome the resource shortage. Obviously, in such situations the focus of the managers is given to short term objectives. Even though an automobile assembly plant is different from a plant in the process industry, the article highlights important consequences of having too little resources.

Considering the specific characteristics of process industries, one understands the peculiarities of conducting step-change innovation projects in such processes. The process is not modular, there is continuous production, and the different stages of the production process are tightly coupled. Each new component added must be adapted to interlock with the pre-existing structure. Such circumstances affect the process of successfully conducting step-change innovation efforts, particularly if there is a focus on efficiency and removal of slack. To develop strategies for how to create routines for step-change innovation in such systems, there is a need to identify concrete organizational structures and processes.

# 5 Methodology

## *5.1 Literature Search*

In the following chapter I will go through the research methodology used in order to answer the research questions. I have chosen a research design and strategy which have enabled me to investigate deeper intriguing aspects of various themes as they emerged. Case study research, inductive logic and qualitative data have enabled me to contribute to academic research by developing a theory of how to manage step-change innovation in the process industry.

The literature was found by three main approaches. First and foremost, I undertook independent literature searches. In the beginning, concepts, topics of interest, and authors guided my searches. Once literature of interest was found, I would go to the reference list and find new authors, books or journals on the respective topic, and thereby develop a deeper understanding. Secondly, my supervisors have shared with me many authors, books and articles of interest during guidance meetings. Thirdly, I investigated articles and other documents belonging to the research project *Step-changes in mature production systems*. As I have been allowed to access presentations and various documents available for participants of the research project, I came across interesting, and highly relevant, authors and journals.

## *5.2 Research Strategy and Research Design*

In order to answer the research questions in a systematic way, I needed to have a suitable research strategy, a plan. My research strategy is building theory from case studies. Eisenhardt's (1989) roadmap for building theories from case studies has been used as a steering tool for this purpose. The case study is a research strategy which focuses on understanding the dynamics present within single settings. They are used to provide description, test theory and generate theory (Yin, 1994). Case studies can employ multiple levels of analysis, and they typically combine data collection methods such as archives, interviews, questionnaires, and observations (Bryman, 2012). Both qualitative and quantitative data can be used. Eisenhardt (1989) outlines several strengths with building theory from case study research. One strength is the likelihood of generating novel theory, as

creative insight is often given to the researcher. A second strength is that the emergent theory is likely to be testable with constructs that can be readily measured and hypotheses that can be proven false. This is because both have undergone extensive verification during the theory building process. A third strength is that the resultant theory is likely to be empirically valid. Eisenhardt (1989) states that the likelihood of generating valid theory is high because the theory-building process is so tied with evidence that it is very likely that the resultant theory will be consistent with empirical observations.

My research design is a blended approach of deductive and inductive analysis, using different types of qualitative data. As the outcome of this thesis will be new theory, I consider the study to have a vast majority of inductive characteristics. However, relevant theory about innovation in process industries has been presented and I have presented established frameworks suggesting how to organize for innovation. Therefore it is also a deductive part of the research design. Consistent with Graebner, Martin and Roundy (2012), I thus consider it misleading to label my research analysis as purely inductive.

For my qualitative data collection, I have used in-depth interviews and written documents. The data from the interviews was recorded via audio recording, and written notes, and later transcribed. During these interviews ideas were probed, and the interviewees provided me with new insight of the phenomenon of interest. The written documents included company internal presentations, public presentations, websites, memos and annual reports.

### ***5.3 Applicability***

I consider the research strategy and design chosen as applicable for answering my research questions. First, I chose case studies as my research strategy. Eisenhardt (1989) argues it is appropriate to conduct theory building from case study research when little is known about a phenomenon or current perspectives seem inadequate because they have little empirical substantiation. She further argues it is appropriate when perspectives in the academic literature on a certain topic or questions, conflict with each other. Since case study research does not rely on previous literature or prior empirical evidence, building theory from case study research in these situations is therefore deemed appropriate. Hence, building theory from case studies seem appropriate when investigating innovation in process industries, as the field needs further research (Lager, 2002; Frishammar et al., 2013a). Further, related to step-change innovation, I have presented the conflicting views on the exploitation-exploration

challenge and the outcomes of implementing process management tools. By conducting case studies, I will be able to present rich data on those particular topics, and hopefully find empirical evidence providing new insights on these matters. My choice of research strategy is also consistent with the theory presented on social study research by Bryman (2012) and what Edmondson and McManus highlight in their article (2007). Second, I have chosen to working with qualitative data. Graebner, Martin and Roundy (2012), present five rationales for using qualitative data. For this thesis, the three first rationales; building new theory when prior theory is absent, underdeveloped or flawed; capture individuals` lived experiences and interpretations; and to understand complex process issues, can justify my choice of data gathering. As interviews are a highly efficient way to gather rich and nuanced data (Bryman, 2012), semi-structured interviews was the main data collection method used. Third, I consider it appropriate to conduct an inductive study to answer the research questions. The reason for this is that I have chosen two significant research questions. I have phenomenon driven research questions, which is why they are broadly scoped (Eisenhardt & Graebner, 2007). I consider my research questions to be important, and that existing theory address the research questions in an inadequate way, therefore I chose an exploratory study.

## ***5.4 Research Approach***

In this section, I will describe the research approach in more detail. With a well-defined focus and an initial definition of my research questions, three different step-change innovation cases within the same industrial company were chosen for study.

### ***5.4.1 Theoretical sampling of Cases***

The selection of cases is important in theory-building research (Eisenhardt & Graebner, 2007). First, one needs to decide whether to conduct a multiple case study, or a single case study. Investigating multiple cases is often chosen for replication or extension of theory (Yin, 1994). Eisenhardt and Graebner (2007) argue that having multiple cases helps create theory that is more robust, as the propositions are more deeply grounded in varied empirical evidence. Dyer and Wilkins (1991), on the other hand, argue that a classical, single case study is the more superior choice. One of the reasons why this holds, they claim, is that the author, due to thorough descriptions given by the author on the phenomena, leaves the reader with the opportunity to seeing the same phenomena in their own experience and research. However, Eisenhardt (1989; 1991) emphasizes that although storytelling is necessary and interesting,

the theoretical insights from case studies arise from a methodological rigor and multiple-case comparative logic. She claims that concepts and theory built from multiple case studies, rest on more powerful empirical evidence. For my study, I have chosen to undertake a comparative, multiple-case study. This choice gives the findings broader applicability, and helps me create valid theory. However, I too believe that telling good stories will help provide valuable insight, and has therefore focused on doing so for each of the cases investigated.

I decided on three cases, all chosen from different operational units and geographical locations, but under the same corporate umbrella. Hence, I knew that the context and general operational environment surrounding the different organizations where the step-change innovation activities had taken place were somewhat similar. As I have undertaken theoretical sampling of cases, it will be likely to replicate, or extend, the emergent theory I present. I consider the cases investigated as a strength of this study. The first case was awarded with a company internal innovation award in 2015, the second with a company internal quality award in 2013, and the last case was awarded with a company internal innovation award in both 2014 and 2015. I therefore consider the chosen step-change innovation cases for being applicable for answering the research questions. I do emphasize, that the cases chosen differ in scope, and in the type of effect, or improvement, the project has had on the production process. Of course, in a cross-case comparison, one cannot compare oranges with apples, and then draw conclusions. However, as all innovations are, by their very definition, unique, I argue the cases are similar enough to answering my research questions.

#### **5.4.2 *Qualitative Data***

Mainly two types of qualitative data are used in this thesis to gain insight in the three cases; semi-structured interviews and written documents. I have used semi-structured interviews for my research, as semi-structured interviews allow the informant to bring up what he or she perceives as most important (Bryman, 2012). An interview guide was made for each case, and modified to best fit each informant. All together in the three cases, 28 people were interviewed (I encourage the reader to see the full interview-list in the Appendix). Four interviews were conducted over phone due to geographical challenges and one interview was conducted at the case company's headquarter in Oslo. The remaining interviews were conducted on-site where the step-change innovation project had taken place. More specifically, seven people were interviewed at the case company's production plant in Karmøy, ten people were interviewed in Sunndalsøra, and six people were interviewed in Høyanger. As this thesis is a delivery within the research project *Step-changes in mature*

*production systems*, I have received assistance in conducting the interviews. I participated in interviewing 22 of these informants. Four of these 22 informants I interviewed alone, however, when interviewing the remaining 18 I received assistance from other students. Six informants were interviewed by a doctoral student and a master`s student at NTNU without my presence. The interviews in which I did not participate are marked in the interview list in Appendix.

For each of the three cases, I have interviewed highly knowledgeable informants, from different hierarchical levels, functional areas and different departments, who have viewed the cases from different perspectives. This is one way researchers limit bias (Eisenhardt & Graebner, 2007). For each of the three cases, I interviewed informants from at least three different departments, all having different areas of responsibility and differing interests in the project`s outcome. Some interviewees preferred being interviewed in pairs. The interviews ranged from 35 minutes up to one hour and 30 minutes, and were later transcribed to make the analysis process more manageable. When reaching my closure, key informants were interviewed again on specific topics. I also contacted key informants to ensure that I had understood the technical facts about the cases correctly, and to discuss aspects of sensitive information. During the process of writing this thesis I have been located at the headquarters of the case company. I have therefore had a unique opportunity for arranging, planning and conducting the interviews, as well as I have had several insightful conversations with employees about the topic of this study. I have travelled to Karmøy, Årdal, Sunndalsøra and Høyanger during the writing of this thesis, and seen the production processes where the step-change innovation projects have taken place. This has enhanced my broader understanding of the cases. Further, employees within the case company have provided me with information about the specific production processes, which has enabled me to better understand statements of the informants, and the technical characteristics of the step-change innovations.

The written documents used for my research are documents such as internal company presentations of the respective step-change projects, documents of project progress and project timelines, as well as background information about the technical production processes. In addition to this, during the process of writing this thesis I have also had access to information about the business system of the company and thereby learned more of how they organize their daily activities. Undoubtedly, this has helped me understand the cases better as I thereby have been familiarized with the language used by the interviewees, as well

as I have been better positioned to understand the challenges and positive elements of the innovation processes.

### ***5.4.3 Data analysis and presentation of Theory***

Analyzing data is at the heart of building theory from case studies, and one of the key steps is the within-case analysis (Eisenhardt, 1989). For that reason, I have thoroughly gone through each case and investigated its peculiarities and characteristics. I have done a detailed case-study write up after each case, and these conclusions and summaries have been important for my further cross-case comparison and theory-building. Consistent with what Eisenhardt (1989) suggests, by using the patterns from each case, I then started the cross-case analysis in the search for similarities between the patterns. I later listed the similarities and differences of my empirical findings. It is difficult to tightly summarize case data (Eisenhardt & Graebner, 2007). Particularly in multiple case studies, it is hard to stay within spatial constraints while at the same time presenting the new theory and root it in the rich empirical evidence that supports the theory. The trade-off becomes ‘Better stories vs. better theories’. As each part of the theory needs to be demonstrated by at least some of the cases, tables or other visual devices are therefore extensively used (Eisenhardt & Graebner, 2007). This I have done when writing up my cases, and in the cross-case comparison. Using tables in the cross-case comparison helps signal the depth and detail of the empirical grounding. I have also presented the findings in multiple ways. I have presented the findings in text and tables, but I have also visualized parts of the theory in boxes and arrows diagrams.

### ***5.5 Validity, generalization and evaluation***

In order to increase the validity of my findings, I have compared my empirical findings and outcome with existing literature, thereby increased my understanding of the findings and achieved a deeper insight in the emergent theory. This is also a way to increase the generalizability of the results (Eisenhardt, 1989; Yin 1994). Eisenhardt (1989) emphasizes that there are no generally accepted set of guidelines as to how this type of research is best evaluated. However, she does mention some criteria. Firstly, the concepts, framework or propositions that emerge should be considered ‘good theory’. The theory built should be testable and logically coherent (Eisenhardt, 1989; Yin 1994). Secondly, the assessment also depends on empirical issues, such as the strength of the method used and the empirical evidence grounding the theory. This point related to the information provided on sample, data collection, data analysis and whether or not the evidence support the theory built (Eisenhardt,

1989). Lastly, Eisenhardt (1989) emphasizes that new strong theory-building research should result in new insight. The goal is new theory, not replication or testing of old. Relating these dimensions of good theory-building research to my thesis, firstly I believe that the strength of my method used, when considering the time spent and overall scope undertaken for this thesis, is good. Further, I believe that my findings and new insights provided is not only a replication of old theory, but new insights. The possibility I have had in working so closely with the case company during this time has given me a good perspective on how such a company in the process industry work every day to improve their production, organization and operations.

## ***5.6 Limitations***

There are several weaknesses in my research. First, limited time and resources has constrained my study. Limited time and resources affect the data gathering, data analysis process and opportunity to investigate the emergent theory's applicability on other cases. The time limitation bounds the amount of theory possible to review on the topic, and also the amount of data possible to collect and analyze. The resource limitation constrained the amount of empirical data possible to collect. I have visited plants in Karmøy, Årdal, Sunndalsøra and Høyanger in Norway, which has enabled me to achieve valuable insight in the cases. However, travel expenses affected the number of trips possible to conduct, and the time spent on-site. The travel expenses were covered by the research project, and funds I had personally applied for prior to start of the semester. Second, there is the concern of informant and researcher biases. Since my goal is to develop an understanding of the 'objective' reality, informant biases, such as retrospective bias or impression management (Graebner et al., 2012), must be considered. I have tried mitigating some of them by triangulating between archival data, individual informant's given information and other informants' information, as suggested by Eisenhardt and Graebner (2007). An example of researcher bias is the 'confirmation bias' (Graebner et al., 2012), but this have been argued to perhaps be more moderate in its effect than informant biases when focusing on objective facts, since they are less subject to interpretation (Eisenhardt, 1989). However, although I have tried being objective, evidently my own opinions and mindset might have led me to focus on themes that I personally believed were the most important ones, when in fact other aspects should have been given more attention. Third, with the large volume of rich data that is provided, it is tempting to try to capture "everything". As I have lacked quantitative data, it has been challenging to assess which are the most important relationships.



# 6 Case Company

## 6.1 Introduction

The case company is Norsk Hydro ASA, a large company in the global aluminum industry. Hydro is an integrated company, involved in all steps of the aluminum value chain, from raw material extraction, production, sales and trading activities. The company has over 13,000 employees worldwide and are involved in activities in more than 50 countries<sup>1</sup>. Hydro produces a range of aluminum products and serves customers within multiple industries, such as electronics, automotive and transport, building and construction, consumer goods, printing and solar products<sup>2</sup>. In general, aluminum is considered a commodity product, even though aspects such as high purity aluminum, environmental production and tailored aluminum products, matters to many customer segments. The capital-intensive industry was hit hard by the financial crisis in 2008, and subsequently there has been a major focus the recent years on costs-reductions and effective production.

Hydro is divided into four main corporate divisions based on the activities in their value chain: bauxite extraction, alumina production, primary aluminum production and products<sup>3</sup>. The first step in the value chain is mining of bauxite. This bauxite then becomes input for the alumina or alumina oxide production in step two. Following this, aluminum is produced with alumina (aluminum oxide) as the main raw material, before the produced aluminum is casted and eventually rolled or extruded into end-products ready for delivery to customers<sup>4</sup>.

## 6.2 Primary Metal

The three cases I will study are all step-change innovation projects in the primary aluminum production stage in the value chain. In the case analyses I will provide overarching descriptions of the technological innovations, which will help highlight why I consider them step-change innovation projects (given the definition of step-change innovation I presented above). Primary Metal is one of four main corporate divisions in Hydro. The activities in the division are mainly related to converting aluminum oxide, and other input materials, into

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<sup>1</sup> <http://www.hydro.com/en/>

<sup>2</sup> <http://www.hydro.com/en/Products/Industries-we-serve/>

<sup>3</sup> <http://www.hydro.com/en/About-Hydro/Organization/Business-areas/>

<sup>4</sup> <http://www.hydro.com/en/Products/Our-value-chain/>

aluminum ingots and other aluminum products. Primary Metal consists of five wholly owned smelters in Norway and four joint ventures abroad. The smelters in Norway are located in Årdal, Sunndal, Høyanger, Karmøy and Husnes, while the joint ventures consists of smelters located in Qatar, Brazil, Germany and Slovakia<sup>5</sup>. Aluminum products can either be produced from recycling of existing aluminum or by electrolysis of alumina. About two thirds of annual production of global aluminum is produced by electrolysis of alumina<sup>6</sup>. The process is as follows: An electric current is passed through the electrolyte at low voltage, but very high current, typically 200,000 amperes and up to 500,000 amperes for the latest generations. The electric current flows between a carbon anode, made of petroleum coke and pitch, and a cathode, formed by the thick carbon or graphite lining of the pot. The carbon anode is consumed in the process. Molten aluminum is deposited at the bottom of the cell and is later drained by vehicles specialized for this task. The molten aluminum is then removed and taken to a holding furnace, where it may be blended to a specified type of aluminum alloy, cleaned and further casted into different semi-products<sup>7</sup>.

Today Primary Metal has support functions for both technology and organizational development in order to support production and development of primary aluminum. The support function for technology is called Primary Metal Technology (PMT) and provides operational support to plants together with long term R&D. The support function for organizational development is the Aluminum Metal Business System (AMBS); a company-wide business-system based on lean-principles aimed at improving overall plant efficiency. The establishment of AMBS in 2006 (previously AMPS, Aluminium Metal Production System) was as a part of Hydro`s long term strategy of being world class within safety, quality, productivity and profitability. AMBS has been developed based on lean principles, and is built on five underlying principles: standardization of work processes, defined customer- and supplier relationships, optimized flow, dedicated teams and visible leadership. Launching of the slogan “bolder implementations” has put Hydro`s focus on how to successfully implement step-change innovations more frequently in today`s operations, and they are setting ambitious targets where the smelters are expected to increase their productivity<sup>8</sup>. One of the questions raised thus becomes; which organizational and technological processes have to be in place in order to fulfill their ambitious objectives? By

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<sup>5</sup> <http://www.hydro.com/en/About-Hydro/Hydro-worldwide/>

<sup>6</sup> <http://www.hydro.com/upload/CMD%202015/Hydro%20CMD%202015%20-%20Primary%20Metal.pdf>

<sup>7</sup> [http://www.hydro.com/upload/Documents/downloadcenter/About%20aluminium/Aluminium\\_environment-and-society.pdf](http://www.hydro.com/upload/Documents/downloadcenter/About%20aluminium/Aluminium_environment-and-society.pdf)

<sup>8</sup> <http://www.hydro.com/en/Press-room/News/Archive/2014/Hydro-keen-to-be-lean/>

conducting a thorough analysis of the three step-change innovation projects, this study hopefully will bring about new insights on how to organize for more frequent step-changes in the aluminum production process.

### *Case Studies*

I will analyze three step-change innovation projects, and answer my research questions by comparing the empirical findings from each of them. The first project to be presented was in December 2015 on the annual Hydro Summit awarded the innovation award for technology development. A new technology was implemented in the wire rod production process at Hydro's plant in Karmøy, ultimately leading to improvements in the work environment, product quality and productivity. The second project was in 2013 awarded the quality award in Primary Metal. It concerns the development of a new recipe for the anode production process in Hydro's production plant in Sunndalsøra, leading to improved performance of the anodes in the electrolysis cells. The last project to be investigated was in 2014 awarded the innovation award for Primary Metal, and was in December 2015 on the annual Hydro Summit awarded the innovation award for products and processes. It is a pilot project concerning a new casting technology for the product area 'sheet ingot', and is a project characterized by substantial technology development. The pilot project took place at Hydro's production plant in Høyanger. What will be evident, although these projects were all successful process innovations, there were several challenges and obstacles needed to be overcome. By investigating the elements, success factors and challenges in each of the cases, I will build the empirical foundation for a conceptual model for managing step-change innovation.

# 7 Within Case Analysis Emulsion Project

“It is a revolution here in the Wire Rod Cast House!”

Process specialist 2, Wire Rod Cast House

## 7.1 Introduction

The first step-change innovation project I will present concerns the implementation of a new process technology in the wire rod cast house at Hydro’s plant in Karmøy. Aluminum wire rod is the main raw material for aluminum used in wires and cables. Karmøy wire rod cast house has been operating since 1967, and is the only cast house in Hydro delivering products to producers of medium and high voltage cables in a global market.



Figure 4: Aluminum wire rod<sup>9</sup>

The cast house has an annual production of 70,000 tones, and the product can be delivered with diameters ranging from 9.5 up to 25 mm. In the cast house, there are three melting furnaces and two wire rod casting furnaces. The production process consists of several steps, from melting, casting, rolling, and lastly the process of coiling the finished wire rod in coils, ready for transportation to customers. During the casting, rolling and coiling of the wire rod,

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<sup>9</sup> Hydro (2015), Internal company presentation, Wire rod unit, Karmøy.

an emulsion made up of different substances is used in the process in order to make the aluminum possible to work with. The ‘Emulsion Project’ in the wire rod unit refers to the project initiated to improve this emulsion. The picture below demonstrates the rolling process of the wire rod, and shows how the emulsion contributes in the casting process, illustrated by the orange line in the figure.

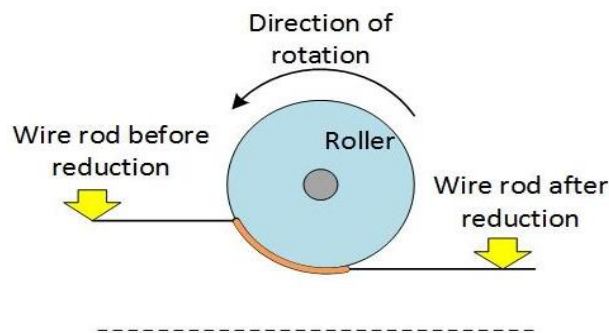


Figure 5: The rolling process of aluminum wire rod<sup>10</sup>

The emulsion has three main functions in the wire rod production process:

- playing a role as a lubricant in the rolling and coiling process
- cooling the wire rod
- cleaning the wire rod

The distinct characteristics of the new technology compared to the previous one is not explained in detail, as it is sensitive information, therefore I will refer to the technological step-change as the “old emulsion” and “new emulsion”. However, what can be revealed is that the wire rod unit found out that the old emulsion allowed for aluminum particles to attach themselves to the oil used in the old emulsion, and that these combined particles later further accumulated in the production system. The cleaning filters could not filter these particles out in a satisfying way, and this was eventually found to being the root cause of several operational problems. The new emulsion the wire rod unit use today consists of different substances than the old emulsion. The new technology has several improvements compared to the old. Firstly, the new emulsion has led to great cost savings. This is both because the deposit from the emulsion is minimized, and because the purchasing price of substances for the mix is greatly reduced. Secondly, the health and safety aspects of the production process

<sup>10</sup> Hydro, (2015), internal company presentation, wire rod unit, Karmøy.

are improved. Previously it was considered a great health hazard to physically emptying the deposit of the emulsion, a process which has now completely changed. Thirdly, the stability of the coiling process and quality of the finished product is greatly improved. Further, due to fewer unplanned production stoppages, the volume of finished products produced in the wire rod unit has increased.

## **7.2 Project initiation**

### **7.2.1 Issues to be solved**

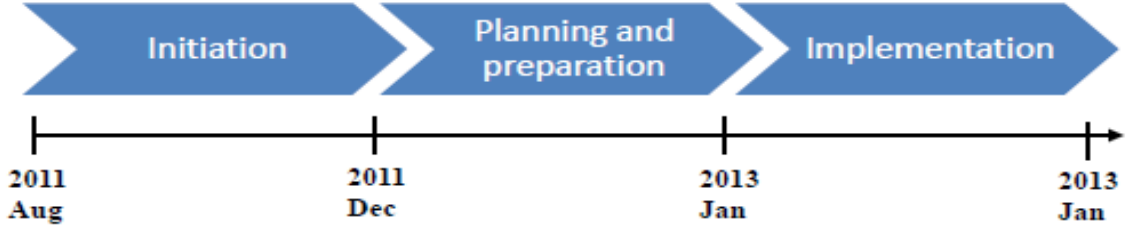
This step-change innovation project was initiated for two main reasons. First, the old emulsion was causing issues related to work environment of the operators. The operators were exposed to vapor of the old emulsion for a long period of time both when changing the rollers in the production process and when the operators had to empty the tank of used emulsion. The tank of used emulsion is placed underneath the rollers and was gradually filled with a slurry of aluminum particles and emulsion. As noted, the waste (slurry) was produced when the emulsion had aluminum particles attached to it during the production process. This tank was emptied by the operators themselves four to six times a year, and no one appreciated this task. Second, the project was initiated to improve process stability. The cast house was experiencing varying and unstable quality of their finished products. The wire had trouble with hitting the coiling properly, and there was a lot of emulsion combined with aluminum and contaminants sticking to the rollers. A parallel process at the time was a pressure on cutting costs. Hydro was currently running a “\$300-dollar program”, aimed at cutting the costs of each tone of aluminum produced by \$300. This led to a focus on the emulsion by the local purchasing department. The old emulsion was a large expenditure post due to both deposit of the emulsion waste from the tank, and costs related to purchase of ingredients.

<b>Driver:</b>	<b>Issues to be solved:</b>
Health and safety	<ul style="list-style-type: none"> <li>• Cleaning of emulsion tank</li> <li>• Cleaning of the rollers</li> </ul>
Cost	<ul style="list-style-type: none"> <li>• Purchasing of emulsion ingredients</li> <li>• Removal of waste</li> </ul>
Product quality	<ul style="list-style-type: none"> <li>• Coiling of the wire rod</li> <li>• Rough surface on finished product</li> <li>• Varying diameter on finished aluminum wire product</li> <li>• ‘Spots’ of oil on finished product</li> </ul>
Productivity	<ul style="list-style-type: none"> <li>• Stoppages in production caused by the old emulsion</li> </ul>

*Table 2: Drivers Emulsion Project*

The drivers are summarized in the table above. There were three main involved departments in the project: The wire rod cast house, represented by both the management and operators. They were the project owner, with a need for an innovative solution to solve operational challenges in their production process. A local project organization was eventually established. It consisted of the unit manager, engineers from the cast house and a local project manager, responsible for the progress of the project. The project manager represented the R&D department in Karmøy, which was the second involved department. Hydro’s R&D department in Bonn, Germany became an involved part after correspondence with various employees from the wire rod cast house. At that time, R&D Bonn was had developed a technology capable of being adapted for the rolling and coiling process in Karmøy. Thus, they became the provider of the new technology needed for the operational improvements.

**7.2.2 Initial contact with R&D Bonn**



*Figure 6: The timeline of the Emulsion Project*

During the winter of 2011, several people at the cast house were trying to find solutions to the operational problems in production. The unit manager was at the time particularly concerned with two challenges; the issues related to cleaning of the waste tank and the unstable production and stoppages they were facing in the cast house. Further, the product quality manager had his eyes fixed on improving the products for the customers, and the operators at the time wanted a better work environment and more reliable production process. At first people believed the operational problems would disappear if one could find a better cleansing of the old emulsion. However, after having invited various externals to discuss the possibilities of a better cleansing, the cast house was not convinced that this alone would solve the issues they were facing.

Parallel to this process, the purchasing manager wanted to lower the production costs, and thus had an incentive to contribute. He discussed possible solutions the challenges the old emulsion was causing on the cost and product quality side with the product quality manager. Together they initiated a search for a possible technical solution, and several mail correspondences with various departments within the Hydro system followed. These mail

correspondences led to the initial contact between Karmøy and a senior researcher in R&D Bonn in the summer of 2011. This senior researcher in Hydro had since 2007 been developing a new emulsion originally meant for rolling mills. His project had been sponsored by the rolling mill division in Hydro and the senior researcher had worked on his research project full time. Although pilot trials had been conducted in the Netherlands in the steel industry, the technology had never been tested in full-scale production. Clearly, it was a wish from R&D Bonn's side to finally try out their technology in a full-scale implementation.

The initial contact did not lead any further, however, shortly after the unit manager at the wire rod cast house saw the possibilities for reaching out to R&D Bonn. The unit manager had personal experience with the rolling mill process, as he had previously worked at Hydro's rolling mill plant in Bonn. As the production process in the cast house in Karmøy has similarities to the process in rolled products, the unit manager saw R&D Bonn as a potential expert environment where a solution could be found. After a conversation between the unit manager and the purchasing manager, the purchasing manager again contacted R&D Bonn and invited them up for a first meeting in Karmøy in the fall of 2011. Three representatives from R&D Bonn were present, and they discussed possibilities for using the technology originally developed for the rolling mills on the wire rod casting process. According to the purchasing manager, the product presented by R&D Bonn to the personnel in Karmøy was far from what they had originally imagined. The technology was at that time completely unknown for the wire rod unit, as it departed quite substantially from the old technology. However, after the initial meeting, the involved parties hoped modifications to it would enable its usage for the production process at the wire rod cast house. The idea of how they could modify the new emulsion to fit the process in the cast house was developed during the initial meeting. The cooperation between the departments was confirmed in December 2011.

### ***7.2.3 Elements characterizing the initiation phase***

There were several elements contributing to the initiation of this project. Systematic problem-solving was one of them. The unit manager emphasizes that to initiate such projects you need to understand what the root cause of your problems is, and see the connection between several production problems to identify the areas for improvement. He explains:

Unless you understand the underlying problem, you cannot start the necessary innovative activities to deal with it. You must be able to understand the whole production process and break down your problem. You need to look at your process from a perspective enabling you think systematically about your problem



and how you work with it. Then, you must look for variation when parameters and settings are changed, because that variation is often the root cause of your problem.

Unit manager, Wire Rod Cast House

He further emphasizes that it is crucial that everyone has the same perception of what the problem is, which can be challenging as people tend to relate the actual problem to what *they* experience in production. Once the problem had been identified, finding the necessary competence became the next element enabling the initiation. Knowing where to find the necessary expertise within an organization is important, and rotating between units is one way of broadening the perspective among employees:

I think it is quite important when you work in an organization like this [Hydro] that the managers have been around in the different business units. Suddenly you pick up something that relates to a future problem somewhere else, allowing you to use that competence later. Likewise, you will be able to find the necessary competence later, because you know where to find it.

Unit manager, Wire Rod Cast House

He emphasizes the importance of having a network, and knowing where certain competencies can be found within your organization. This was an important element for the initiation of this project. Otherwise, they might have just continued like they had always done, the unit manager explains. Operator 1 also highlights this particular issue related to the initiation of the project: “The reason I think the project was not initiated sooner is linked to the technical competence on the concrete matter. The technical competence needed to solve the operational problem was previously not sufficient in wire rod, or Karmøy, organization”. From his point of view, the issues had not been properly solved earlier due to a lack of expertise in that particular area. However, the fact that the technology originally was not meant for their process, and had never been implemented full-scale before, was a risk for the organization:

We were at a cross-road. Either we could continue to improve the already existing process, or we could go for something completely new and make a step-change. This was the risk we had to take. The new emulsion had never been tested large-scale before, only in the laboratory.

Process specialist 1, Wire Rod Cast House

What process specialist 1 is referring to is the risk associated with implementing a technology which prior has only been tested in a research environment. The surroundings differ from those in a production facility, thereby affecting the performance of the technology. In this particular instance, process specialist 1 emphasizes amongst other things that the large speeds they achieve in their production process, were higher than the speeds in the test-environment. However, the management in the wire rod unit had strong faith in the technology, and was willing to take this risk. The interviews, however, showed that there were mixed feelings regarding this new, and rather radical, change which was about to come. Skepticism toward the technology was evident:

Some people felt like me, having a lack of faith that this would turn out as good as it did. It was a surprise that it turned out as good as it did. Not only to me and other operators, but to the people around as well, such as the people in the administration. . . When people have been working here for 20-30 years and you are going to start changing them, there will always be skepticism.

Operator 1, Wire Rod Cast House

There was skepticism to how the new technology would perform, which may be a result of having worked for several years with the same process technologies and routines. By working in routines, you might end up making a defined solution space of what is possible to achieve within the production process you know so very well.

Something that further characterizes the initiation of this project is the involvement of employees in the cast house, which is one way of ensuring engagement and motivation. Process specialist 1 explains that the unit manager took the responsibility for involving the employees. The unit manager has focused on involving the entire organization at all levels:

I believe that in order to implement these step-changes, you need to organize for a way of working which allows the people who are meant to own the project, to be involved in the entire process. If the R&D department shows up with a technical solution and says: 'Here, do it like this', and I have not been a part of developing it, and do not know what it is, I might refuse to spend time on it.

Unit manager, Wire Rod Cast House

What the unit manager emphasizes is the importance of involving your employees, enabling them to develop ownership to the new technology or process developed. There was no doubt that several of the interviewees truly appreciated to be involved and given responsibility. Process specialist 2 states: “He [the unit manager] gives you an enormous and rare ownership. He trusts us and believes that we can do it. . . This ownership has only positive effects on us. You end up doing a much better job“. Process specialist 2 further explains that the involvement they refer to, includes responsibility of project tasks, the opportunity to engage in new processes, and the opportunity to increase their knowledge about the overall production process. There is no doubt that this involvement has greatly affected their motivation for contributing and engaging in the project.

### ***7.3 Technology implementation***

#### ***7.3.1 Organization and Implementation***

After the cooperation had been confirmed, preparations started. It had been decided that they were willing to risk one week of production to test out the new technology. During the months prior to implementation, representatives from R&D Bonn visited Karmøy to train various employees in the cast house in how to make, and use, the new emulsion. According to the process specialists, the representatives did a great job in helping the production unit prepare. The unit manager further explains that during the phase prior to the first test in production was characterized by extensive communication between the departments. The preparation phase lasted for one whole year, from December 2011 until January 2013. There was no training of the operators in how to use the new emulsion during this phase. The reason for this was that the content of it was under great secrecy, as they were currently filing for patent on the technology. Therefore, only a few of the managers at the cast house knew the content, and were the only ones who would be allowed to make changes to it in production.

In January 2013, they were ready to go live. The researchers had adapted and modified the new emulsion in their research facilities in Bonn, and the production site had been prepared. The initial implementation was conducted during one intense week, with representatives from both the cast house and R&D Bonn participating. In practice, what happened was that they emptied the entire production system of the old emulsion, cleaned the whole system properly, before the system was re-filled with the new emulsion. This was an intense week with good cooperation between the representatives from the different departments. According to the project manager, “Everyone was very motivated, some even worked 18-20 hours per day. We did not even notice whether it was a day in the weekend or a weekday. Our goal was to

succeed”. To everybody’s satisfaction, the first week of producing with the new emulsion was a huge success. The production process in the cast house seemed to be better than ever. Therefore, it was decided to continue with full-scale production using the new technology. There was a close follow-up by R&D Bonn during the first weeks, and Karmøy kept in contact by phone and email, and sent tests of the new emulsion to R&D Bonn each week.

Up until this stage in the project, the cooperation had been very successful. The project manager states that they worked on the different issues together along the way in order to solve them: “Despite of all the problems and all the challenges we faced, we supported each other”. In the following months, representatives from R&D Bonn came to Karmøy once every three months. The laboratory in R&D Karmøy carried out analysis of the new emulsion and sent the results back to Bonn. The cast house was also satisfied at that time, but there was one issue:

He [senior researcher, R&D Bonn] asked if there was something in particular he was supposed to work on before he left back to Bonn, and I asked him if he could try to solve the issue with keeping the rollers clean of the new emulsion. However, he was never able to find a solution to it.

Process specialist 1, Wire Rod Cast House

Little did the parties know at this time that this particular problem would be one of the issues ending up causing headaches for the wire rod production unit only a few months ahead.

### ***7.3.2 Realignment with existing Machinery***

There are risks associated with implementing new technologies. On the one hand, the technology may not perform as intended. On the other, it may solve the issues originally planned for, but affect other parts of the production process and thereby create new problems. Although the initial implementation was a success, new operational challenges soon emerged:

After seeing the first coiling with the new emulsion, we thought: ‘Wow! This is the best coiling we have seen!’ and we were all very satisfied with the results and thought it was great. However, it did not take long before new problems arose.

Operator 2, Wire Rod Cast House

The first three to four months, the new emulsion worked optimal, and the production issues disappeared. However, as it had different characteristics, the new emulsion eventually caused new problems in the production process. These related to:

- Tearing of the wire rod during the coiling process
- Portions of the new emulsion clogging parts of the production process
- Corrosion on the rollers and other parts of the existing production system

The project manager emphasizes that these were challenges they had not foreseen: “Of course we knew that we would face some issues after implementing the new technology. But after the implementation, certain problems arose which we had never forecasted”. At this point, the unit manager explains that they struggled finding the root cause of these new operational challenges. As this new technology had not been tried out full-scale before, the knowledge about how to solve the new problems was limited. Neither the cast house in Karmøy, the R&D department in Karmøy or R&D Bonn knew the solutions to the new operational problems. As time passed, the new challenges turned out to be the source of an increasing expenditure for the cast house:

We lost faith. At that point we felt as if this was the dumbest thing they [the management in the wire rod cast house] had ever done. We were making no money, having large maintenance costs, and we are exhausting ourselves out there on the machines. On top of that, there was so much wire rod tearing and also other problems.

Operator 2, Wire Rod Cast House

As the months passed, the new, technical challenges proved to be very hard to solve. Further, they needed to maintain continuous production, which put a pressure on the involved parties:

We did not have a lot of time to solve the new problems arising in our production process. We only had limited time to make critical decisions, due to the continuous production of wire rod in the cast house. Further, because of the continuous production, we also knew that we could not risk too much either.

Project manager, Wire Rod Cast House

The wire rod unit found it hard to deal with the operational issues, as the continuous production created a time constraint. Further, interruptions in the production demand a quick response-time in order to keep the downtime of the production process as low as possible. This complicated the process of solving the new problems when implementing new technologies. Time passed, and the problems continued. One element further complicating the processes of solving the problems was the patent Hydro was filing for the new technology.

Only a few persons in the unit were allowed to do necessary adjustments to it. This might very well be one of the factors affecting why some were dissatisfied with the information given during the trouble-shooting. As operator 4 states: “I thought it was bad information. . . We did not receive any response if we asked about something. There was not much communication. We were not informed about what they were doing”. According to operator 4, this was an issue often discussed among the operators during the project. Working on a shift-arrangement, further complicates the communication:

There are changes that you might not pick up. Often some people on one shift are informed, and then they are supposed to tell the next shift, and then the next shift. However, this is not always done. Sometimes communication can be poor.

Operator 2, Wire Rod Cast House

The statements above clearly indicate that there were some dissatisfaction with the information flow and communication within the unit. The continuous production and a pre-determined shift plan are characteristic of the process industries complicating the communication. The geographical distance in this project also complicated the communication between the involved departments:

It was a bit troublesome as this was a project with people located in Germany, particularly the communication. The people in R&D Bonn have been very supportive during the project, but they are located far away. They are not close on the operational problems, and do not feel the challenges the same way we do. When you introduce a new technology, when you make a step-change, you easily let go too soon, before the process has fully stabilized. We are still not done.

Unit manager, Wire Rod Cast House

While trying to solve the new problems, the interviewees thus highlighted three aspects complicating the communication process; patent-filing; shift-organization; and geographical distance to R&D Bonn.

### ***7.3.3 The need for follow-up***

Employees in the cast house in Karmøy thought the representatives from R&D Bonn left too early:

What we have been bad at, what Hydro has always been bad, is that we easily get people involved and on the spot when they are needed in a project, but these people often do not stick around until the project is done.

Process specialist 1, Wire Rod Cast House

As the researchers from R&D Bonn were no longer present, the local competence in the cast house became crucial to solve the operational challenges. As operator 1 explains, “I think the main reason it turned out well, was because of the expertise here in the cast house. Including knowledge about operations, the wire rod production process and cleansing of emulsion”. As new production technologies in process industries must be fitted into the already existing production system, expertise of both the old and the new is important due to the complex linkages between the production process stages. Process specialist 1 thought R&D Bonn should have been more present in the later stages due to their knowledge: “We do not have the specific knowledge necessary. We have our experiences here in the cast house with the old emulsion and can work with that, but this is a completely new thing for us”. Process specialist 2 also points out the issue of losing access to the necessary competence too soon:

I am thinking related to their knowledge. In order to analyze what they thought could have gone wrong related to the new problems . . . They have received tests every week afterwards from us so they have sort of had it under control, but the thing is that they are not here. Further, it might be wrong of me to think like this, but, if I participated in owning this project, then I would have put a person with sufficient knowledge to follow it up in later stages, perhaps a year.

Process specialist 2, Wire Rod Cast House

When R&D Bonn left Karmøy after the initial implementation, so did the extensive knowledge of the new technology. Communicating via phone and email was not sufficient:

We tried to describe the problems in production, and they tried changing the composition based on what we described, but that was not a good way to work. It would have been a lot better if they were here and saw the problems with their own eyes. It took a long time before they came back. I think a whole year went by before they came back physically from Bonn. Obviously, our descriptions of our problems might not have been perceived, or interpreted, the correct way.

Process specialist 1, Wire Rod Cast House

The senior researcher in R&D Bonn, however, saw the issues around the problems arising in later stages from a slightly different perspective. His statements indicate that the wire rod unit was under-staffed and that the continuous production in the unit was the main obstacles when trying to solve the new problems arising in later stages:

The main problem was that the available resources out in production were very small. . . The project manager was always very busy with other tasks in addition to this project, and he was not free to work solely on this project. . . Several of the problems occurring needed fast response.

Senior researcher, R&D Bonn

From his point of view, insufficient resources and a staff shortage in the cast house unit were the main issues related to the problem-solving process. Further, the unit manager notes that he was very busy with other tasks, and could not devote as much time to the project as he wanted. The senior researcher from R&D Bonn continues, “From my point of view, we needed time to get to know this new technology. We needed to gain experience with it, and you learn a lot from solving problems”. Clearly, there were different perspectives on this matter. This underlines the importance of agreeing on such things in advance of the project. Differing experiences and interest in the project evidently affect the position each party take.

The many challenges in the production after implementation has left the wire rod unit with valuable experiences related to organization of step-change innovation projects. The unit manager explains: “We did not plan the production phase well enough, from my side. I underestimated the transition between the initial project phase and the production phase. This I have learned. . . The whole organization has learned from it”. In this case we have seen that agreeing on areas of responsibilities in the later stages affect the smoothness of the implementation of new technologies in the production process. You may solve one operational problem by changing a parameter of implementing a solution, but this again will most likely affect other parts of the production process. If the production unit no longer has the opportunity to contact the technology supplier or expert environment, and still lacks sufficient competence to deal with the new problem, they might be forced to go back on the solution, and then try to solve the original problem instead. This almost happened in this step-change project, as the cast house unit was very close to giving up.



#### **7.3.4 Close to giving up**

New versions of the emulsion were developed based on the tests sent to R&B Bonn from Karmøy and descriptions of the operational problems. However, the researchers in R&D Bonn were not able to find a solution. The wire rod unit tried several solutions themselves, and kept communicating with R&B Bonn as the months passed. However, after several months of trying and failing, the wire rod unit was starting to lose faith:

At that time we were quite despaired and we were just about to give up. We were on the edge of whether or not we should go back to the old technology or not, because we simply could not fix the problems. Our maintenance department did not have time to do anything else but cleaning the rollers.

Process specialist 1, Wire Rod Cast House

Several other interviewees also emphasized this crossroad. Apparently, the costs of maintenance had increased to a level not economically viable, as well as the daily work of the employees in the unit was characterized by stoppages and frustration. That was when a problem-solving meeting was held, in order to try figure out what the root cause of the problems was, and what the unit would decide to do. Should they go back to the old emulsion, and try solving the original problem a different way, or should they keep the new emulsion, but somehow modify it? There was a substantial problem with wire rod tearing and too much friction, due to shortage of lubrication. After this meeting, the local research department finally found a solution to the problem. A few of the employees in the local research department in Karmøy who had been sending the tests to R&D Bonn, put a substance in the new mix in a hope for improvement. They tried it, and improvements were finally seen to the new operational challenges they had been struggling to solve ever since the implementation. Thereby, the emulsion used today is a modified version of the one they originally received from R&D Bonn. Reflecting on the overall project, the unit manager notes that:

What is critical when you make a step-change is to put up a formal project with a project manager who has the project as his main task. If you do not do that, then you will not succeed. Of course, it depends on whether or not you have many other daily tasks in production, but in general, the employees in production do not have sufficient capacity to make a step-change. We need to take over the step-change once it is finished, and then incorporate it into new routines. . . A

production unit is not organized for conduction larger innovation projects on their own; they are organized for continuous improvements.

Unit manager, Wire Rod Cast House

Based on lessons learned from the project, the unit manager emphasizes that the production unit, as of today, does not have the necessary organizational structure to ensure effective progress in step-change innovation projects. Having a project manager dedicated to the project from the start is a lesson learned in the wire rod unit. Further, receiving assistance from outside the organization is noted as desired.

#### ***7.4 Project success factors and challenges***

There were several critical elements leading to the eventual success of this step-change innovation project. The employees in the cast house have contributed substantially to the success of the project with their local expertise, and the engagement and motivation of employees to contribute was secured by involvement of the local organization. Delegation of responsibility in project-related tasks and meetings to gather employees for cooperative and systematic problem-solving were some examples contributing to the project's success. The initial implementation of the technology was a huge success, but eventually new problems arose. In process industries, when conducting process innovation projects, new operational problems might occur in later stages due to the complex linkages between parts of the production process. If new, complex problems arise later you might still need the competence of the external expert department. The problems occurring in this particular project called for extensive coordination between the departments after the initial implementation, which was challenging as the expert department was located in Germany. Further, setting aside time to solving the new operational proved challenging as the unit needed to maintain continuous production and carry out daily tasks. Follow-up by R&D Bonn was not sufficiently agreed upon in advance, and was noted to be an important lesson for the unit. During the transitioning from the formal project and a new and stable production process, areas of responsibility need to be agreed upon as this phase turned out to be far more complicated than imagined. In projects where an external expert department is contributing, having the opportunity to access the knowledge also after the initial implementation can be crucial. The success factors and challenges of the overall project are summarized in the two tables below:

<b>Project success factors:</b>	<b>Description:</b>
<b>Support of local management</b>	The local management supported the project and were willing to take the necessary risks. Internal resources were set aside for the project and the managers prioritized it.
<b>AMBS- tools and systematic problem-solving</b>	Daily meetings, weekly meetings and meetings across shifts were emphasized as valuable. Usage of activity logs and other tools were important to managing the project. To clearly understand the root cause of the problems, the unit worked systematically with the problems using AMBS-tools.
<b>Organizing for involvement</b>	Delegation of responsibility increased the involvement and engagement of employees. Employees were motivated for receiving the new process technology to improve their workday.
<b>Cooperation between departments</b>	Good cooperation during preparation, the initial implementation and early period after implementation. Coordination and communication.
<b>Visible leadership</b>	The unit manager spent time out in production with his organization to solve the problems. Delegating responsibility and involving employees. Cannot have too many other tasks.
<b>Technology</b>	The new technology itself was an important success factor.
<b>Local expertise</b>	The competence and knowledge in the cast house of the production process. This eventually enabled them to solve the new operational challenges themselves, without the help of R&D Bonn.
<b>Failure-OK</b>	There was a need to continuously develop and try out new, possible solutions to the new problems. A climate where the employees dare contribute with their best, although the results might not turn out favorable, was emphasized as very important.

*Table 3: Project success factors Emulsion Project*

<b>Project challenges:</b>	<b>Description:</b>
<b>Skepticism</b>	Initial skepticism among the personnel in the cast house, they were uncomfortable with being 'test rabbits'. Consequences may be a lack of engagement and contribution during implementation. The process of learning the new technology might slow down.
<b>New technology</b>	Hard to predict the consequences of implementing the technology.
<b>Secrecy</b>	Hydro was filing a patent. Not everyone could know the composition of the new emulsion and thereby participate to their fullest in searching for solutions. This caused frustration.
<b>Continuous production and time constraints</b>	Solving new problems was challenging with a time constraint and the absence of R&D Bonn. Tight schedules make solving extra problems a challenge. R&D Bonn noted that the main challenge during the later stages when issues arose in production, was a lack of sufficient time dedicated by the wire rod organization.
<b>Geographical Distance</b>	The experts on the new technology were located in Bon. The management in the cast house would have preferred it if they were geographically closer, enabling them to come see the problems.
<b>Communication</b>	At times the communication between R&D Bonn and Karmøy was not sufficient, particularly during the later stages. Some of the interviewees emphasized that they would have liked more information.
<b>Follow-up by Bonn</b>	The wire rod unit wished that the researchers from Bonn had followed up better. Particularly because of their knowledge about the new technology.

*Table 4: Project challenges Emulsion Project*

# 8 Within Case Analysis Anode Recipe Project

“Dramatic transition. Completely fascinating.”

Governance manager, PMS

## *8.1 Introduction*

The second case to be investigated is a step-change innovation project conducted in the Sunndal Carbon unit at Hydro's production plant in Sunndalsøra. Sunndal Carbon has produced anodes used in the electrolysis process of aluminum production since 1968. Today the production capacity is 80,000 tons of anodes annually. In the electrolysis cell, aluminum oksyd, carbon and electricity react with each other to produce aluminum and carbon dioxide. In the technology used for aluminum production, the so-called “prebaked” technology, a typical anode is made up from a mixture of petrol coke, coal tar pitch and a portion of recycled anode residues from the electrolysis process. These various components are mixed at high temperatures, and later baked in furnaces. The anode is ‘rodded’, set in a pot, and put into an electrolysis cell. The carbon anode participates in the chemical reaction and must be capable of operating at very high temperatures without deforming. A need to improve the performance of the Sunndal anodes in the electrolysis cells, initiated the anode recipe project.

The technological change in the anode recipe project was the development of a new recipe for the aggregate composition of the materials the anodes consist of. In Sunndal Carbon, an increasing issue of slot-cracks in the anodes during operation in the electrolysis cells led to the start of an investigation of what the cause of this problem could be, and how the unit could approach this problem to solve it on a permanent basis. Anode deviations are today at a minimum level due to the new technology. The frequency of deviating behavior of the anodes during operation in the electrolysis cells is significantly reduced, as is the number of wrecked anodes after production.



*Figure 7: Anode cracked during operation in the electrolysis cell<sup>11</sup>. The picture above shows that a large portion of the bottom left corner of the anode has fallen off due to slot cracks.*

The technical change cannot be revealed in detail, but what can be explained is that in this project, the amount of fine grains in the aggregate-mix was reduced and made more fine, and the share of coarse grains was increased and made coarser. In order to achieve the increased fineness of the fines, the settings in the milling circuit needed to be changed. The main technical challenges in changing this process were related to milling certain ingredients to a finer grain size by adjustment in the air classifier, while at the same time obtaining sufficient capacity of the production process.

## **8.2 Project initiation**

### **8.2.1 Issues to be solved**

The anode recipe development project was mainly initiated because Sunndal Electrolysis discovered that the anodes produced in Sunndal Carbon had a tendency to crack often in the electrolysis cells. The quality of the anodes in aluminum production affects the overall efficiency and productivity of the electrolysis cell. The amount of metal produced in an electrolysis cell increases linearly with the current, and increasing the current is therefore cheap bought capacity. However, increasing the current also puts more pressure on the anodes and raises the need for more robust anodes. When an anode cracks, parts of the anode falls down into the “bath” in the electrolysis cell, and thus disturbs the aluminum production. The anode must then be changed. The slot cracks problems became an expensive and increasing issue during 2010/2011. One reason for the increasing amount of cracked anodes was that

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<sup>11</sup> Hydro, (2014), internal company presentation, Carbon unit, Sunndalsøra.

Sunddal Electrolysis had been gradually increasing the current in their electrolysis cells over the years. The drivers are summarized in the table below:

Driver:	Issues to be solved:
Slot cracks	<ul style="list-style-type: none"> <li>• In anodes</li> </ul>
Cost	<ul style="list-style-type: none"> <li>• The cost of the anodes in the electrolysis cell</li> </ul>
Product quality	<ul style="list-style-type: none"> <li>• Quality of the anodes</li> </ul>
Productivity	<ul style="list-style-type: none"> <li>• Stable production in an old plant</li> </ul>

Table 5: Drivers Anode Recipe Project

This project was organized after what is referred to within Hydro as a ‘three-party cooperation’; a production organization, an expert department and a governance function. The production unit was Sunddal Carbon. They were the owner of the problem, as their anodes were the ones performing below standards in the electrolysis unit. The governance function was represented by Primary Metal Support (PMS). At this time there were four people working in PMS who were responsible for coordinating and allocating funds for various support-activities in different business areas. In this project, PMS is represented by a governance manager, who was responsible for the Carbon-area in the Globally Fully Owned Smelters (GFOS) in Hydro. He had ownership to solving this issue due to his role. He was in a leader position, responsible for the budget and capable of calling into meetings where people would need to show up. The expert department is represented by Primary Metal Technology (PMT). PMT is the R&D department of Primary Metal in Hydro, with researchers mainly located in either Årdal or Porsgrunn. The person chosen to be the project manager in the project had recently been employed in PMT where she was working with material development. Sunddal Electrolysis also played an important role for the success of this project, as they are the customer receiving the anodes. Further, Årdal Carbon experienced problems with their anodes, and was involved.

8.2.2 The Governance Role

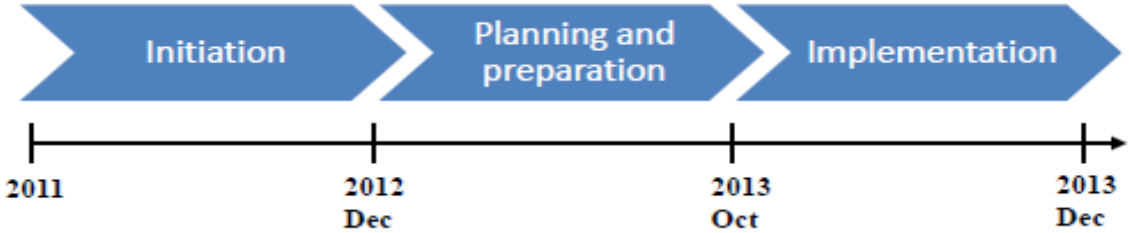


Figure 8: The timeline of the Anode Recipe Project

In 2011, the plant manager at Hydro`s production plant in Sunndalsøra put up a task-force to improve the performances of the electrolysis cells. Amongst other things, they were struggling with cracked anodes in production. Sunndal Electrolysis receives anodes from various locations, including Sunndal Carbon. To find out which anodes were underperforming, and have the respective suppliers improve the quality of their anodes, Sunndal Electrolysis followed closely up on the performance of each type. They found that the anodes from Sunndal Carbon were underperforming, and communicated this to the new unit manager of Sunndal Carbon. There was established a good dialogue between Sunndal Carbon and Sunndal Electrolysis, and the departments from then on communicated on a weekly basis to follow up this matter.

At this time, the governance manager in PMS contacted the new unit manager of Sunndal Carbon to find solutions to the anode problems. He was knowledgeable of anode production processes due to past work-experiences, and was now in a leader-role with authority to make decisions regarding allocation of support-funds for improvement projects. The governance manager called in to several meetings with various managers in Hydro working within the carbon area, to seek for possible solutions. He put up what is called a “Core Team” for carbon; a platform where people working within the carbon area could meet up to discuss problems, improvements, standardization and best-practices. He has played in central role in initiating this project, as his role gave him the right mandate:

If there had been such a person there prior, this project and change in the production process would have been done a long time ago. . . My role gave me the opportunity to see a problem. Someone had to sit with the overarching competence to discover the problem, and at the same time have sufficient authority to say; ‘We need to do something about this’.

Governance manager, PMS

The governance manager had a voice that meant something organizationally, and as he had the necessary authority to given instructions to whether or not to prioritize a specific matter, the project manager states that his role was crucial for the initiation of this project. She emphasizes that it is important to have someone with authority to push, as workers on the plants are usually caught-up with daily problems and therefore often do not prioritize to engage in new initiatives. The process specialist in Sunndal Electrolysis agrees:

There is a purpose in having someone who are able to prioritize resources on the cross of plants. Everyone wants funding, that is just how it is. If you do not have someone with the overarching responsibility of delegating available resources, the ones who scream the loudest will get the most funds.

Process specialist, Sunndal Electrolysis

She believes having a governance function can help research departments spend funds for innovative projects more wisely. From this, there is little doubt that the governance manager from PMS played an important role in identifying the problem, allocating resources, and contributed to the overall initiation of the project.

### ***8.2.3 A step-change needed***

Prior to the start-up of this project, the Sunndal Carbon organization worked hard to improve the quality of their anodes by minimizing production process variation. In 2011, a slot crack project was initiated, that mainly focused on stabilizing the production process. They hypothesized that an unstable production process of the anodes was causing the problems in the electrolysis cells. The area leader states: “Without these previous efforts we would not have been able to implement the change in our production process”, and emphasizes the necessity of having engaged in activities and efforts related to minimizing process variation. The idea behind this focus on process stability was to capture the parts of the production process in the need for improvement, and thereby improving the anodes` performances. Noise and signals from the statistical process control charts would guide which areas to focus their efforts. However, neither of these efforts led to improvements to the crack-related problems.

Time passed without any improvements of the failure rate of the anodes recorded, despite great efforts in process stabilization. Sunndal Carbon was on target on all parameters, but it simply did not have the desired effect. During the spring of 2012, the new unit manager at Sunndal Carbon was eager to receive help from PMT in solving the problems with the performance of the anodes. His willingness to let PMT participate in the project was noted by the project manager from PMT as very important, as it the expert environment therefore could work closely with the production unit to solve the problems. The governance manager suggested to PMT that a person should be set aside to work on a project with the aim to develop a recipe- philosophy for the anode production process in Sunndal Carbon. This person would gain knowledge to understand the recipe they were currently using, do research



about the various anode-recipes, and also investigate the recipes` effect on the strength of the anodes. This person later became the project manager of the anode recipe project.

As there were no significant improvements of the anodes in the electrolysis cells, in 2012 the people involved in the improvement efforts in Sunndal Carbon decided to chisel up 28 anodes in order to see if there was something they were missing. These anodes were randomly picked out of production, and were not cracked visual to the eye. After chiseling them, everyone understood that they were up against a problem which would not be solved through variation minimization and fine-tuning of the production process. As process specialist 2 explains:

Almost all the anodes were cracked inside. That was when we reached the conclusion; *‘Houston we have a problem’*. That was when we realized that we were the ones with the actual problem. It was not Sunndal Electrolysis, it was us.

Process specialist 2, Sunndal Carbon

The chiseling of the anodes made Sunndal Carbon realize that they would need to do something drastic to their anode production process, as well as it also gave new energy to the project. However, at this time they were not yet sure how they could solve the problem.

It turned out, the technical solution to Sunndal Carbon`s anode production problems would be based on an already existing technology from another Hydro plant. There were two key people setting the focus on that particular Hydro plant: the unit manager in Sunndal Electrolysis and the governance manager in PMS. The unit manager in Sunndal Electrolysis experienced the trouble of changing the broken anodes in the electrolysis cells, and therefore had an incentive for solving the cracked-anode problems. He had recently worked for a longer period of time on that particular other Hydro plant, and the anodes in the electrolysis cells worked perfectly fine there. He therefore communicated to other managers at the Sunndal plant that he wanted anodes similar to the ones from that Hydro plant. Parallel to this, the governance manager in PMS noticed gaps in the improvement work at Sunndal Carbon; nothing focused on the actual strength of the anodes. Neither of the improvement initiatives focused on the recipe of the paste of the anodes. In Sunndal Carbon they had used the current recipe for approximately 20 years. The governance manager communicated with researchers within PMT, and discussed the recipe they used on the other Hydro plant, which used a different recipe of the aggregate composition of the anodes than Sunndal Carbon. However, the other Hydro plant had a newer, and quite different, production process technology. The

question then became whether or not a similar aggregate composition to solve the issues in Sunndal Carbon. The particle distribution of the materials was different. Firstly, it consisted of a lower overall percentage of the fine grains, but the fine grains were made finer. Secondly, the overall percentage of the coarse grains used there was higher, and the coarse grains were even more coarse and robust.

#### ***8.2.4 Getting people on board***

Eventually a group of people, including the unit manager and process specialist 2 in Sunndal Carbon, were convinced to try a new anode recipe. The governance manager spent much time discussing the potential solution with others in the system, as a part of what he refers to as ‘an anchoring process’; getting people on board with the idea of a new anode recipe. He further emphasizes that an informal meeting between him and the unit manager at Sunndal Carbon was very important for the start-up of the step-change project:

The support from the local production organization was essential. I believe the meeting between me and him [unit manager Sunndal Carbon] where we talked loosely and informal, and where I told him that I would like for him to try such a test, was very important. . . I think that one of the success criteria was to discuss the issue with the unit manager, and get him on board.

Governance manager, PMS

Although it was risky, the new unit manager was willing to take the risk, which was important, as the management can stop anything and prioritize anything. Once he was on board, the rest of the organization needed to be convinced. However, there was a challenge in getting people aboard for the new solution. The governance manager reveals:

One of the researchers in PMT had previously informed people of the development of the recipe, but the smelters had not responded to this. So I knew there was a challenge here. . . Several people told me: ‘You cannot put an old, classical, tore-down, overloaded plant like that to be compared with a new and modern one. You will not be able to pull that off’. That is what some people told me, included some of the best researchers on this field within PMT.

Governance manager, PMS

Shortly after this, the governance manager from PMS travelled to the other Hydro plant and spoke with one of the engineers there with the purpose of learning more about the

characteristics of their anode production process. During that meeting, the engineer revealed that he had previously participated in successfully turning around an old production plant, similar to the one in Sunndal Carbon, to run on the new anode aggregate recipe. The governance manager was now convinced that this could work: “What remained at that point was to get the technology expert department (PMT), which would drive this project towards success, on board for the solution”. He initiated a workshop, a ‘kick-off-meeting’. In this meeting there were representatives from Sunndal Carbon, Årdal Carbon and PMT. The engineer from the other Hydro plant was present and shared his experiences, and many skeptical voices disappeared:

I felt that it was something that moved the project forward from just being a theoretical discussion, to getting a more practical point of attack. . . To have him [the engineer from the other Hydro plant] on the start-up meeting was very important and useful. It was a turning point.

Process specialist 2, Sunndal Carbon

The project manager from PMT had prior to this been reading about the aggregate composition in papers, and was positive to the idea. She also emphasized how important it was to the project that someone had actually done it before. Evidently, the experience of the engineer from the other Hydro plant was as a motivational factor for the project manager and other employees.

Once they decided to try the new recipe technology, a small group with representatives from Sunndal Carbon and PMT was appointed as responsible for carrying out the anode recipe project in December 2012. They would conduct test-runs out in the production plant and follow up. The project manager from PMT was the owner of the project, while the others had expert knowledge in anode materials and mill-circuits. These experts were usually located in Sunndal Carbon and Årdal Carbon, while the project manager, was originally located in Porsgrunn. Throughout the project the project manager travelled to Sunndalsøra whenever necessary. According to the governance manager, various parties within the Hydro system had known about different recipes for the anode-aggregate for several years. However, there was a need to put the current knowledge in a context. This was also emphasized by the area leader in Sunndal Carbon: “We knew about the technology. . . But earlier we simply did not want to implement it”. He further explains that the Sunndal Carbon organization really needed someone to the overall take responsibility to drive forward such a large project. The process

specialist 2, on the other hand, emphasize that a lack of sufficient knowledge in the Sunndal Carbon organization, and PMT, on the specific field was the reason they had not solved the issues earlier.

The pressing issue was related to knowledge of the fact that we had a bigger problem than we thought. Additionally, PMT did not have sufficient competence on the field to tell us how we could achieve making anodes with finer fines. We did not have any recipe or enough competence to do anything sensible about it.

Process specialist 2, Sunndal Carbon

Apparently, the particular competence needed to solve the crack-related problems needed to be found. Further, although researchers within Hydro had known about the technology, there had been some disagreement on whether or not this new technology actually would solve the problems.

### ***8.3 Technology implementation***

#### ***8.3.1 Involvement and mutual learning***

After it was decided to try the new recipe, the project manager was in December 2012 put in as an extra resource at Sunndal Carbon, responsible for the overall progress of the project. She was not there every week, but visited the plant on a regular basis. From the start, the project manager from PMT extensively involved the workers in the production unit to engage them in the project. The operators were skeptic to her presence at first. However, this changed:

The project manager did a very good job. She was energetic and pushy, had us involved in test-runs and explained to us what she expected from us. That was very important. . . I am very pleased with the personal involvement in this project and I definitively believe that is one of the success factors. If you simply receive a directive, or are told: ‘This is how you are going to do it’, from a distanced person, then it will not be the same type of involvement from our side out in the production.

Operator 1, Sunndal Carbon

One of the ways the operators were involved, was that they were offered to join in on weekly meetings, as well as the project manager was constantly out in production discussing the

project with the operators. Interviews showed that the way the project manager and other managers involved the rest of the production unit led to an increased motivation and engagement. The unit manager of Sunndal Carbon states:

The project manager is very knowledgeable and has a great way of interacting with the production-organization where she was constantly asking questions. What I find particularly interesting here, is that learning happens both ways. The project manager learns things as well, and that way we both grow. The operators learn a lot when she is out there with them in the production unit.

Unit manager, Sunndal Carbon

Mutual learning characterizes this project. The various parties brought different sets of skills and knowledge into the project, and through communication and cooperation they found solutions. The project manager from PMT emphasizes that she learned a lot about the anode production process during this project, and gives the production unit a lot of credit:

What I brought in of competence was how to run a test in production during operation. I did not know anything of paste fabrication. I learned about that production process during our trials, because then I was present and the operators taught me. They do not understand that they are the ones who taught me what I know today. They laugh at me whenever I tell them, ‘You are the ones who taught me this! You are the ones who taught me how it this is all connected’.

Project manager, PMT

By organizing the project this way, with a project manager out in the production unit, the operators learned more about the characteristics and underlying principles about their production process, while the project manager achieved a greater insight of how the different parts of the production process related to each other in practice. This enhanced her understanding of how changing certain parameters would affect the overall production process.

### **8.3.2 *Planning and communication***

The project manager focused on extensive planning, and used meetings as the arena for communication and sharing information. With great experience with running tests in production from previous work, she has learned to prioritize planning:

You need a plan. What are you going to do, and in what order? You need to have thought about what you are planning on actually doing. And you also need to be present. If you think that something will turn out one way, but turns out another way instead, you need to be present to make the necessary adjustments.

Project manager, PMT

As she emphasizes, not only must you plan what you are going to do, but also plan for having to adjust for things that might not go according to plan. The project manager focused on holding meetings with PowerPoint-presentations as the basis for communication and information. She states that she sees this as the best way to communicate, as nobody has the time to read fat reports. Further, the operators were always given information about the project's progress in the different stages. The operators work shifts, and therefore they might not receive information. The area manager explains that this is challenging:

Imagine an organization where there is a five-week cycle; some of the other operators you do not meet for several weeks, so how do you get the information out to those people? The flow of information is always a challenge in a shift-working organization.

Area leader, Sunndal Carbon

What the area manager highlights is that within an organization working on a shift arrangement, therefore, in an innovative project it is beneficial having a third party taking on the responsibility for assuring sufficient communication and knowledge about the project. Process specialist 1 agrees and adds:

Usually you cannot sit down like we do now and discuss things properly. Normally you get the information from the previous shift or by an email, and evidently, the more people you have on one shift, the more difficult it is to reach out to everyone.

Process specialist 1, Sunndal Carbon

Therefore, it is important to have a project manager which is 'hands on' and continuously out in production engaging in conversations with the operators and other employees.

### 8.3.3 *Test trials*

Detailed test trials were conducted prior to the full-scale implementation. There were obstacles and insecurities they needed to overcome prior to implementation of a new recipe:

- Slot cracks – would the new recipe solve the problems of cracks in the anodes?
- Recipe – how would they modify the new recipe to fit the limitations of the plant?
- Fines – would it be possible to produce the finer fines in their existing milling system?
- Process parameters –alignment of the rest of the production process to the changes.

These challenges were addressed in reverse order.

The milling process of the materials making up an anode is complex and Sunndal Carbon needed an understanding of how to adjust other process parameters if the recipe was changed. Which other parameters would need adjustments to align the rest of the materials to the changes? They risked having a capacity-problem in production by changing settings of the aggregate mix. To learn which other adjustments would be necessary, an initial lab-test was conducted. Those lab-studies worked as a point of direction, and showed that they would not need to drastically change their other current production settings.

As the carbon plant had a very old production process technology, technical challenges might occur once changes to certain parameters and settings were made:

The question was whether the production plant could deliver what we wanted, technically. This was what the tests would show us. The tests would also reveal what kind of operating regime the operators would have to relate to after the change. That was our main challenge; the production facility's shape and condition.

Governance manager, PMS

However, they did have an advantage; Sunndal Carbon had a second parallel mill standing right next to the one they currently used. In order to achieve finer fines and changing the composition of the three input substances, the entire milling process needed to be changed. With the parallel mill, changing parameters on the equipment had a lower risk. They could

simply do the necessary technical adjustments on one mill, and change back to the other when the test was finished. This evidently lowered the overall risk for the project.

The next step was to conduct a mill-test, to see if their current production system actually was capable to produce the finer fines. This test was conducted in the first week of January, 2013, on the extra mill. It lasted for only a few hours. During this test, no other parameters were changed, and the few anodes produced were not followed up in production, as the purpose of the test was only to check the capability of the existing machinery to produce finer fines. The test turned out positive, and they proceeded.

In the second week in January 2013, a 24 hour-test was conducted where process parameters were adjusted based on the results from the initial lab-test. They produced two ‘sections’ of anodes with the purpose of knowing whether or not the material-balance in the production process would add up. Would the production be able to produce the new recipe over a longer period of time? The recipe had been made on the background of many assumptions about the material-flows in the system, and needed verification. Would the test reveal unforeseen problems in later production stages? These anodes were followed-up throughout the process, all the way to the electrolysis cells, to learn about the risks of conducting a larger test at a later stage. The project manager was present at all times. Operator 1 undoubtedly sees the advantages of having someone present during tests, and explains what might happen if not:

You look at the test-runs differently. Then you might just show up at work, trying to run the machines, and if it goes downhill then it is a lot easier to stop the test-run, compared to if you have a terrier on your shoulder watching you and being positive, has extra capacity and who knows what she is talking about.

Operator 1, Sunndal Carbon

They ran their production process in the carbon-unit for 24 hours and produced a specified number of anodes for the electrolysis cells. The anodes were closely followed-up by the preceding departments, and their performances in the electrolysis cells were tracked. The first test turned out positive. However, the number of anodes produced was not large enough to verify if the new recipe did in fact solve the problems. They now planned for what would be the ultimate test for whether or not the new recipe would become the new standard in their production process. In this stage it was important that Sunndal Electrolysis specified how many anodes needed to be produced successfully for them to agree to a permanent change.



They agreed that one week of production would be sufficiently to approve for full-scale implementation.

The second large test lasted for one week. This was sufficient time to notice if the recipe needed adjustments, and to verify if the recipe did in fact solve the problems related to slot cracks. The project manager explains that the phase between the first and second stage was all but flawless:

Every time I came to the unit there was something else that had happened in production. It could be something completely unrelated to the actual project, other operational problems. We tried to run the second large test three-four times without being able to do so, because of other problems completely unrelated to the project.

Project manager, PMT

Eventually the timing was good. In May 2013, one week of production was completed with the new recipe and went through a thorough verification process in the electrolysis cells. All anodes were put in a group of cells over a period of 4 months. This long time-frame was the main reason why a clear specification from the Sunndal Electrolysis on the number of anodes needed to approve the new recipe was so crucial, as they could not simply ‘run another test’. The test was an unequivocal success and all the slot cracks in the anodes were completely gone. After this, Sunncal Carbon was ready to implement the new anode recipe in their production process.

#### ***8.3.4 Full-scale implementation***

In October 2013 the full-scale implementation started. There were several issues they had yet to figure out. What they had received from the other Hydro plant was a recipe not made to fit their production system, and although the tests so far had been successful, there were insecurities related to production parameters and settings and mix of material flows. During the implementation, indeed, new problems arose. Amongst other things, a capacity constraint of the current machinery led to production stoppages. Process specialist 1 explains how the change in the anode-aggregate composition to finer fines affects the overall anode production process: “In order to achieve finer fines, you will need an increased number of rounds through the mill to crush the grains finer. Therefore, you end up with a capacity problem in the production process. That is what we have been struggling with”. With longer time needed for

the milling process, the capacity of the mill decreased and affected the coordination of the fine grains` production rate with the rest of the material flows. Changing certain aspects of a production process affects other parts of the process. The complexity creates the need for later adjustments:

It is all interconnected. If I told the operators to change the amount of a certain material in their current production mix from 20% to 15 %, then there would be too much of another material. By changing that parameter, I have changed the whole balance of materials. We clearly saw several challenges related to this both during, and after, the implementation process.

Project manager, PMT

What the project manager explains is that by solving one problem, others might arise in the production process. As the production process is complex and interconnected, changing one setting or parameter will affect other parts of the production chain. Therefore, modifications and adjustments in later stages were necessary. The project manager has followed up necessary adjustments, also after the implementation. She states; “It is always important to follow up changes. Particularly if there are incidents that are out of the normal, then it is very important that you have someone who is not too busy with daily operational issues”. The project manager is still visiting Sunndal Carbon. Operator 1 emphasizes that it is very important that the unit still have access to her expertise. The final recipe, which they use today, is an approximation of the recipe used in Hydro`s other production plant, but adapted to the Sunndal anode production process.

### ***8.3.5 An Extra Resource***

It became evident through the interviews, that one main advantage of involving a third party when conducting innovative projects relates to resource constraints in the production unit.

We do not need a new organization to come and tell us what we are doing wrong, because usually we know. What we need is someone to come and help us with challenges and assist us in fixing the problems. . . She [project manager, PMT] has helped us focus and contributed out in the production plant with taking tests, which has influenced others. . . . She should have been cloned.

Unit manager, Sunndal Carbon

The unit manager in Sunndal Carbon emphasizes the important role the project manager has had. She has solved a resource constraint and motivated the production unit by participating herself. The unit manager's perspective on resource shortage is most clearly shared by others:

Where will you go to find the necessary resources to contribute in these projects? Those people are supposed to be a part of the project, but at the same time, we have continuous production. We currently have an example of one of the engineers here who has been very involved in an innovative project, but no one is stepping in and doing the job he would normally do.

Area leader, Sunndal Carbon

What the area leader emphasizes that when engaging in innovative efforts, a resource constraint arises. Thus, his impression is that innovative activities are often conducted at the sake of the quality of other daily operating tasks. It seems there is a trade-off between keeping up with world-class performance in the daily operating activities, versus contributing with time and competence to an innovative initiative. The project manager emphasizes the fact that when she comes in as an external, she does not have her focus on the daily operation and problems. Her focus is on the innovation project:

I do not drown in these daily issues. . . As an external I can say, 'Today I will work on this for three hours and focus on finishing that plan', and that opportunity you do not have in the production unit. You never have three hours continuous where you can sit down, focus and finish a product. There might be meetings, or something happens in the production process.

Project manager, PMT

This can be seen as a natural side effect of leaning up production processes: there is not much slack time for employees to spend on larger projects, as most of their time is already devoted for operational tasks. The area manager highlights that he does not believe they would have been able to conduct the project the same way, even if they were more people of each shift. He believes there is a need to have someone there who knows the overall goal and the ambitions of the project and can make sure that same knowledge is distributed to every shift.

## ***8.4 Project success factors and challenges***

There were several important elements contributing to the success of this step-change innovation project. The role of the governance manager in PMS was very important for the project's initiation. Further, the previous work the Sunndal Carbon unit had done on process stabilization was a critical success factor for the initiation phase.

The project manager from PMT came in as an extra resource, and ensured that the whole organization were engaged and participative. There was extensive involvement of employees at all levels in the local organization. By being out in production, the project manager was able to draw on the local expertise of the process specialists and operators about the anode production process, and together they managed to find a new recipe, suitable for the old existing production system at Sunndal Carbon. The detailed planning of the project and test-runs evidently was an important success factor, combined with good information flow and communication. The project manager communicated with the production unit continuously during the project. Several emphasized that one of the most essential tasks for a project manager during a project is handling the communication and information flow, particularly in shift-working organizations. The project manager organized for meetings, as well as she and the other process specialists in the unit ensured good communication and coordination with Sunndal Electrolysis throughout the project.

It was emphasized by several interviewees at Sunndal Carbon that the presence of the project manager was a solution to the daily time constraints they face due to running lean processes. Further, the project manager played an important role as a red line, carrying the project through the different phases. She knew the overall state and goal of the project at all times, and could communicate this information to the local organization. Her focus was also different, as she focused entirely on the project when in production. A very important aspect of this project is the follow-up in later stages. The project manager, and the knowledge she had gained about the new technology and production process, was not lost to the production unit. This follow-up was important to deal with new technical problems that arose during and after the full-scale implementation. Realignment of the new technology with the existing system proved to be difficult, but the project manager was there for the Sunndal Carbon unit to contact. The tables below summarize the success factors and challenges of this project:

<b>Project success factors:</b>	<b>Description:</b>
<b>Governance Role</b>	Having a person with sufficient authority to initiate projects.
<b>Involvement and mutual learning</b>	The whole organization was involved from the very beginning. This created engagement and motivation. There was mutual learning happening between representatives from R&D and the production unit.
<b>Two separate mill circuits</b>	A parallel mill minimized the risk of conducting the test-runs.
<b>Cooperation between departments</b>	The good cooperation between PMT, Sunndal Carbon and Sunndal Electrolysis was very important in this project.
<b>Planning</b>	Extensive planning for the project, attest-trials, unforeseen events and follow-up.
<b>Project Manager</b>	The project manager focused on planning, communicating and presence. With sufficient time and energy devoted to the project. Her presence solved the time constraint and assured progress. She functioned as a red line throughout the project.
<b>Local expertise</b>	The competence and production process knowledge in the carbon unit was important.
<b>Follow-up</b>	The project manager was present to handle the necessary adjustments and technical challenges arising after the initial implementation.
<b>Communication and information flow</b>	Good communication during all stages of the implementation phase. Both internally within Sunndal Carbon and with other units. Information to operators greatly affected motivation and gave a feeling of ownership.
<b>Presicion Culture: Systematic Problem-solving</b>	Extensive work done prior to the step-change project in variation minimization and process improvements. Possible to see effect of changing parameters.

*Table 6: Project success factors Anode Recipe Project*

<b>Project challenges:</b>	<b>Description:</b>
<b>Old technology</b>	The existing production system in Sunndal Karbon was very old and affected the possible options for solutions to solving their operational challenges.
<b>Skepticism</b>	In order to being able to start implementing the technology, skepticism among some operators needed to be overcome.
<b>Doubt</b>	Would this new technology help at all? Disagreement within the expert department if it could help the problems.
<b>Technical Challenges: Capacity Constraint</b>	Technical process challenges occurred as a result of the changes. Changes in anode aggregate composition led to capacity constraints in production. Therefore, new routines for balancing the components in the mix needed to be found, and learned by everyone.
<b>Time Constraint: Daily production</b>	Daily production makes larger innovation projects and problem-solving challenging. Workers in the ongoing operations usually have full schedules during one shift, so extra problems besides the 'normal' operating variance is noted as challenging to handle.
<b>Time</b>	The time horizons are long, thereby the verification process is so extensive. It takes a very long time before you get response.
<b>Qualification process</b>	Getting the customer, Sunndal Electrolysis, to articulate how they would do the qualification process for the anodes once the large test.

*Table 7: Project challenges Anode Recipe Project*

# 9 Within Case Analysis AFM Project

*“One critical success factor is that we have very routinized, experienced and proficient operators”*

Unit manager, Høyanger Cast House

## 9.1 Introduction

The third case investigated is a pilot project of the Adjustable Flexible Moulds (AFM) casting technology. It was initiated in 2012, and the technology implementation was conducted early in 2014. The pilot project took place in the cast house at Hydro’s production plant in Høyanger. In Høyanger cast house they produce sheet ingot and low alloyed products of aluminum. The AFM technology is used for casting of sheet ingots, which are rectangular ingots of aluminum several meters long. The sheet ingots are used on the rolling industry and have several application areas, such as; lithographic printing plates; packaging; building and general engineering. The AFM technology was developed by the cast house technology provider, Hycast AS, in cooperation with researchers at Hydro’s Research Center in Sunndalsøra, RTD. Hycast is a subsidiary fully owned by Hydro, with headquarters in Sunndalsøra. Hycast has expertise within technology and process development, complete cast house support, project management and engineering. They also provide casting technologies for customers outside Hydro<sup>12</sup>.

The AFM technology has several advantages over the previous casting technology. The cast house in Høyanger is now able to cast alloying in series, as well as the geometry of the aluminum sheet ingots is improved. With a flatter surface, the milling required by the customers in their subsequent production process to get the right level surface they need before rolling, is reduced.

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<sup>12</sup> <http://www.hycast.no/AboutUs.asp>

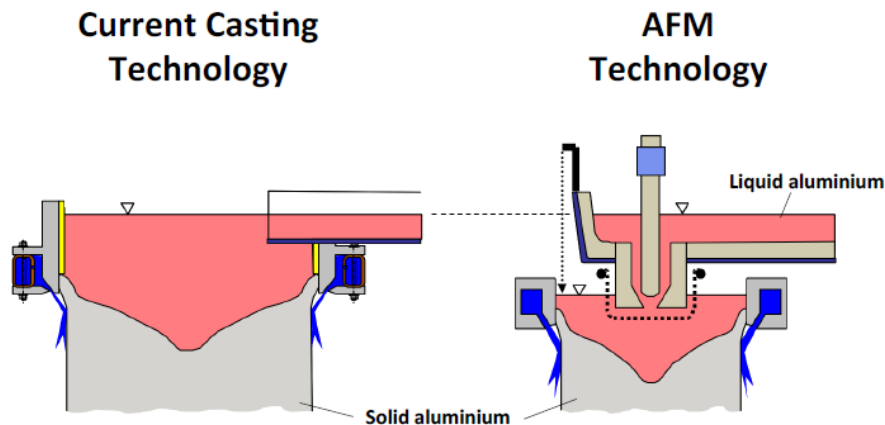


Figure 9: The current casting technology and the AFM casting technology<sup>13</sup>

Further, the technology has advantages related to safety and work environment. Operators are lesser exposed to potential dangers of molten metal, as the new casting system includes a process control function, automating the start and end of a casting operation. Further, as the new casting tables are both flexible and adjustable, the number of mould changes needed to produce different alloys and sizes is significantly reduced. Amongst other things, this lowers the traffic risk inside the cast houses as crane and fork lift operations<sup>14</sup>. In Høyanger and Årdal, a full-scale implementation of the technology was started in 2015, and will be completed by the first quarter of 2016. However, the focus of this case analysis is only the pilot project.

## 9.2 Project initiation

### 9.2.1 Issues to be solved

Based on a market study of future market segments Primary Metal business area conducted in 2012, expanding sales in the automotive market proved to be attractive. However, products sold to the automotive industry often have a need for specialized and advanced aluminum alloys. The AFM casting technology was therefore a technical solution to the challenge of serving a wider range of advanced alloys to new potential customers, as well as existing key account customers. Besides strengthening Hydro's capability in producing complex alloys and increase their product portfolio, the new technology also has advantages related to safety and work environment. Further, the casting costs are reduced with the new technology. The main drivers for initiating of the project are summarized in the table below:

<sup>13</sup> Hydro, (2015), internal company presentation, Cast house unit, Høyanger.

<sup>14</sup> <http://www.hydro.com/en/Press-room/News/Archive/2014/Hydro-to-invest-in-advanced-casting-technology-targeting-automotive-industry/>, Øyvind Breivik, 2014

<b>Driver:</b>	<b>Advantages of AFM:</b>
Market opportunities	<ul style="list-style-type: none"> <li>• Competition within markets for simple aluminum alloys created a need for investigating new market opportunities</li> <li>• AFM technology enables wider product portfolio</li> <li>• Increased capability in producing complex alloys</li> <li>• Feedback from key account customers to Hydro revealing that Hydro would not be a future strategic supplier if they did not expand their product portfolio.</li> </ul>
Work environment	<ul style="list-style-type: none"> <li>• Employees not exposed to molten metal due to automatic start-up and end of casting</li> <li>• Removal of FiberFrax</li> </ul>
Product quality	<ul style="list-style-type: none"> <li>• Better geometry on the sheet ingots</li> <li>• Automatic start and flexing improves the geometry of the casted the casted aluminum ingot</li> </ul>
Cost reductions	<ul style="list-style-type: none"> <li>• Less scrap production caused by complex alloys with existing technology</li> <li>• Removal of FiberFrax removes the surface scrap due to friction</li> <li>• Removes the cost of purchasing FiberFrax</li> <li>• Less cut-off due to start-up effect, and reduced scalping before rolling.</li> </ul>

*Table 8: Drivers AFM Project*

### **9.2.2 “The Innovation Team”**

In this pilot project there were several involved parties, but related to the research questions of this study, I have focused on three involved departments; Hydro`s research and development department (RTD) in Sunndalsøra, Hycast and the cast house in Høyanger. Research on the AFM technology had for several years been conducted by RTD Sunndalsøra, prior to the technology being taken over by Hycast. The scope of the project can roughly be divided in three parts:

1. One aspect of the pilot project is the development of the new casting technology and equipment. RTD Sunndalsøra has played a major role in the development, but today it is further developed, designed and produced at Hycast.
2. The second aspect is the activities of the sales department in the product division and the contact towards the market and customers. This includes sales and test-deliverables.
3. The third is the technology implementation in the cast house in Høyanger. This includes the alignment of the AFM technology to the existing system, training of the operators, on-site preparations, etc.

The three departments were involved with the technology development, implementation, and the overall project organization and progress. Hycast, being the technology supplier in this step-change innovation project, was responsible for delivering the AFM casting technology to fit the specified customer requirements. The cast house in Høyanger was the organization to



receive the technology, responsible for preparing the site for implementation and usage of the technology. The three parties organized themselves differently towards this pilot project based on their areas of responsibility and project deliverables.

**9.2.3 Prototype developed**

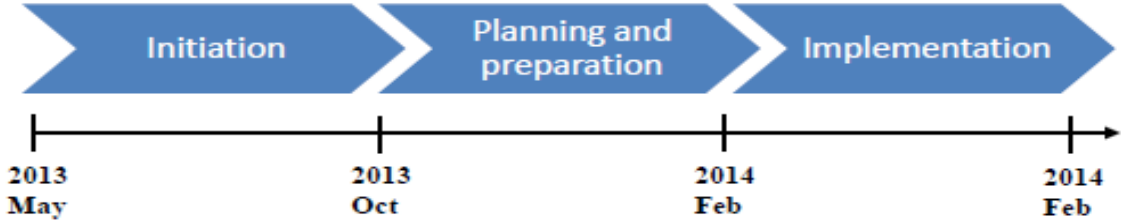


Figure 10: The timeline of the AFM project

The development of the AFM technology started as a research idea at RTD in Sunndalsøra. Each year Hydro allocates funds to an internal project aimed at further developing the casting technology for sheet ingots. A senior researcher from RTD explains that the idea of the adjustable casting form is very old, but it was not until 2006/2007 that the researchers in RTD initiated its further development. A prototype was developed in 2009 at RTD, where Hydro has a testing facility. According to the unit manager in Høyanger, there were several drivers initiating the development of a prototype in 2009 of the AFM technology. Firstly, the demand for aluminum for the newspaper segment, and related segments for low-alloy products, was dropping due to the trend of online news and declining sales of papers and magazines. Further, key account customers communicated that they would not consider Hydro a strategic supplier in the future if Hydro did not broaden their product portfolio. Secondly, fierce competition from China and the Middle East for ‘easy’ aluminum alloys made it difficult for Hydro to compete on price. Thirdly, Hydro experienced a growth in the use of aluminum in the car-industry market, due to stricter emission standards and demands for lower fuel consumption.

**9.2.4 Organization of Project**

After a strategic customer target study conducted by Primary Metal business area in 2012, it was established a steering committee eventually initiating this pilot project. In May 2013 it was decided at corporate level to complete a pilot project on implementing the AFM technology in Høyanger, prior to a later full-scale implementation of the technology in both Høyanger and Årdal. The product area ‘sheet ingot’ was the client in this project, and they were responsible for setting up a project management and announcing a project manager. The

person eventually chosen for this task was located in Sunndalsøra. However, this person failed to meet many of his responsibilities:

It did not have a good outcome. What happened was that we [Hycast] ended up communicating directly with the cast house. There became a ‘back-trading’, where the project manager would summarize afterwards. He was always lagging behind on what was actually happening. . . We should have had a clearer project management for the project communicating directly with us, and Høyanger.

Manager 3, Hycast

The formal project manager did not prioritize the project sufficiently. Due to the complexity of this pilot project, sufficient communication and coordination was necessary in order to ensure project progress. The unit manager at Høyanger also emphasizes that the project manager pointed out by the steering committee did not devote enough time to the project: “He gave us a few challenges. . . I think he was present in Høyanger perhaps once during the entire project, and that was at the start-up meeting”. The safety representative in the cast house emphasizes the importance of the people dimension when running such projects: “In a project, the implementation phase and project structuring phase very much depend on which persons hold the various positions. You need to have the right person at the right position at all times”. The main challenge arising as a result of the absence of the project manager was the coordination and communication between Hycast, RTD and the cast house. The project was formally organized as a commercial project, but, as this project required substantial technology development, it turned out that this choice of organizing the project was not optimal. The interviews showed that the project became something in between a pilot project and a commercial delivery:

What we missed within Hydro was some sort of guide, or apparatus currently available, of how to run pilot projects. This we did not have, we simply could not find any. . . Hydro should have had a different model for it. A model where there is a cost-spilt and a spread of risk; a different kind of cooperation. Shortly, there should have been a better way to organize such projects.

Manager 2, Hycast

What Manager 2 from Hycast felt was missing in the Hydro system, was a suitable ‘template’ for pilot project organization that this project could have followed. Due to the absent project

manager, the project was off to a rough start with many loose threads, and changes in the organization and project working-method were necessary. As a result, an internal ‘reference group’ was, according to the unit manager in Høyanger, set up in August 2013 to ensure project progress. Their goal was to ensure the site was ready for the arrival of the AFM casting form in February 2014. The internal reference group consisted of available resources in the cast house in Høyanger; representatives of the operators; the local management in the cast house; the maintenance department; the mechanical department and HSE. There were also representatives from Årdal, RTD and one from Hycast participating. They made an extensive project plan with a list of tasks that needed to be completed prior to the scheduled implementation. The unit manager explains that the months during the summer and autumn of 2013, became very hectic. For a unit manager with a full schedule, taking on a project such as this in addition to all the other areas of responsibility, resulted in a large workload. However, due to an injury, the unit manager was forced to work from home for a few weeks. This was actually beneficial to the project as he was then able commit more attention to the project:

At that time I had a surgery in my knee, and I was therefore forced to work from home at when the pilot project was at its busiest. This enabled me to work on the project from home, and I think I must have worked 150% that month. . . . Actually, the injury was a bit of luck. Because, I would never have been able to work on the project as much as I did if I would have been present here in the cast house with all the other tasks I normally have.

Unit manager, Høyanger Cast House

A unit manager already has his day filled up with responsibilities, and taking on the responsibility to ensure progress in a pilot project such as this in addition, is not an ideal situation. Clearly, the initial project management put this pilot project off to a rough start, but luckily, the cast house in Høyanger did the efforts necessary to ensure progress.

### ***9.2.5 Technology Development***

This was a project characterized by extensive technology development. Having a more present project manager in similar projects in the future, was an important lesson:

An advice to the project owner is to have a project management that is more ‘hands on’. . . . It would have been better actually, when I reflect on it, that either someone from RTD, Hycast, or the organization in Høyanger had the role as the project manager. That way you would have achieved a more closeness to the

project. That is important, particularly in such a project where there is substantial technology development.

Manager 3, Hycast

What Manager 3 from Hycast emphasizes, is that projects where further technology development is necessary prior to implementation, increases the need for coordination and communication between involved departments. This puts greater demands on the project management and creates a need for being closer to the involved parties. Although the cast house did a great job in putting up an internal reference group, having a project manager solely dedicated to the project alone, with enough time and resources, might have eased the communication and coordination. As the area leader in the cast house explains:

There was no communication. They [Hycast] do things the way they believe is the right way, and then later present a technical solution to us, which is not compatible with our existing equipment. This creates a need for modifications of the new technology in later stages.

Area leader, Høyanger Cast House

There were communication and coordination challenges between the involved parties related to the further technology development prior to the initial implementation. To have well-functioning communication and cooperation is emphasized by the senior researcher from RTD to ease the technology implementation: “The technology provider must draw on the competence available. A thorough job needs to be done in the early stages, prior to the design has been decided upon”. He emphasizes that this will ease the process of aligning the new technology with the existing system, and points out that it is the responsibility of a project manager to assist in this coordination between involved departments.

## ***9.3 Technology Implementation***

### ***9.3.1 Design Reviews and Preparations***

The implementation of the AFM casting form was scheduled to February 2014. Prior to the scheduled implementation, the cast house in Høyanger needed to go through extensive preparations; mechanical connections needed to be in order; programming of equipment; electricity; water, and so on. Design reviews and training of personnel was also undertaken. During this stage of the project, the unit manager focused on created an arena for

communication, enabling people to meet and discuss progress. Once a week the local reference group met to discuss the project`s progress and to follow up tasks.

You need to develop a sense of ownership, as there is no good having an arena for meeting and follow-up if people have not done what they were supposed to do in between. Working this way, people in the organization became very motivated to make the project succeed.

Unit manager, Høyanger Cast House

The meetings structure they put up enabled them to make sure people followed up on the activities they were to complete in between the meetings. This was a success and the local reference group was able to get things done. During this period the cast house had a good cooperation with Hycast:

We were able to establish a good cooperation with Hycast on what we refer to as design reviews, where a few representatives from our organization would travel up to Hycast. There they would look at the equipment together, and discuss the technical solutions and drawings. If there were things we meant would not work, or saw any flaws, we could have a dialogue and make suggestions for changes or improvements.

Unit manager, Høyanger Cast House

The design reviews were highlighted by both the cast house in Høyanger and Hycast as very valuable for the project`s success. Suggestions to improvements and modifications on the technology were given, to ensure the technology`s fit with the existing machinery.

During the planning and preparation stage, involvement and engagement of workers in the local organization was an area of focus. As in the other step-change projects presented, there was extensive involvement of the operators, and this was emphasized in the interviews as a success factor for the project. Involvement in this particular case, related to training of the operators in using the new equipment, and communication given about the pilot project from the local management. The operation of the AFM technology calls for less manual work and more automation. Therefore, it was necessary to develop a new set of skills and competence of the operators in the cast house. For this reason, in November 2013 and January of 2014, the management in Høyanger gave everyone the opportunity to travel to Sunndalsøra and receive training in using the AFM technology:

We were allowed to watch them cast and see how the system worked. We quickly found that this was some interesting and good stuff. You saw the possibilities of what you could accomplish if you made the new technology work. . . We quickly saw the advantages. . . You have to involve people. A lot of people are sensitive towards new things. They might have worked here for 30 years, and suddenly there is something new in production that drastically changes your workday.

Operator 1, Høyanger Cast House

The trainings were emphasized by all interviewees as one of the most important success factors for the implementation process. The operators could try out the new technology for themselves, and learn about the advantages of the technology before they received it on site.

It is always a positive thing to be included from the very beginning. It truly gives you more ownership to the new technology, at the same time you become more familiar with using the new technology before it is incorporated in the existing system in the production process.

Operator 2, Høyanger Cast House

Operator 2 views the early involvement as perhaps the most important thing the management in Høyanger did in preparing the organization for the implementation: The senior researcher from RTD also see the training and involvement as important:

I believe it is important that they come up here and get a feeling that they are contributing in developing the equipment by using their existing competence. That way they develop a sense of ownership to the equipment. I believe this is very important. Compared to if they have just heard about the new equipment, and one day suddenly it is there.

Senior researcher, RTD

The trainings at RTD Sunndalsøra proved to be a huge success. It is evident that the management in Høyanger did a great job in involving workers early and prioritized to get employees familiarized with the new equipment. However, not everyone felt the communication and involvement was sufficient. Operator 3 emphasizes that he would have liked there to be more communication, and in particular in the form of meetings. Evidently, to ensure everyone receives enough information, can be challenging.

### ***9.3.2 Construction-period***

After the on-site preparation stages during the fall of 2013 and training of the personnel, in January 2014 there was a two-week period referred to as a 'construction-period'. During these weeks all the last necessary modifications on site was finished prior to the implementation of the new form. As the senior researcher from RTD had extensive knowledge of the AFM technology, he was hired in by the unit manager in Høyanger during this period to function as a site manager. As the form needed to be realigned to the existing machinery, extensive programming needed to be taken care of, as well as there was a need for quality testing of all the technical equipment, air and water supply. These were some intense days with great effort and motivation:

During the 14-day period where we prepared the site, prior to the first casting with the new technology, there was an extreme effort by the whole team. In particular the maintenance personnel and the representatives from Hycast did a great job, as well as the senior researcher from RTD. And we made the deadline.

Unit manager, Høyanger Cast House

Due to a good cooperation, the three involved departments ensured that the site and technology was ready on time. The senior researcher from RTD emphasizes the attitude of the cast house unit as the most important success factor for the implementation during this period:

One very important aspect was the positive attitude in the Høyanger cast house. They had been waiting for the equipment for some time and were very positive. I believe it is very important to have the cast house on board and that they are positive to the new equipment and have faith in it.

Senior researcher, RTD

He believes one of the reasons employees in the cast house have been so positive to the new technology, is that they the chance to get to know it in advance during trainings. The employees in the cast house evidently contributed greatly to the project's success, and the attitude and knowledge of the operators was emphasized as crucial:

It is unique, really. I have never experienced such a thing before. Usually operators do not appreciate new technologies because it involves change. It means extra work and new things to relate to. But here, everybody was positive. They

understood that this was important and useful for them. . . That was the largest success factor the way I see it.

Manager 2, Hycast

The unit manager in the cast house undoubtedly agrees. The efforts put in by the cast house, RTD Sunndalsøra and Hycast to meet the deadline for the first casting were great, and they made it; the first casted sheet ingot was a success and sold to a customer. Despite the rocky start with an absent formal project manager and some challenges related to communication and coordination, the three parties managed to meet the deadline and deliver a good result for the first casting. However, some weeks after the initial implementation and hand-off of the technology by Hycast to the cast house in Høyanger, technical challenges emerged.

### ***9.3.3 The following Months***

After the new AFM casting form was implemented, there were some months with technical problems in production. The following week after the new form had been fitted to the system, commissioning was completed, and then Hycast left. During the spring of 2014, around 20 test-orders were casted in the cast house with the new AFM casting form. Although the first casting with the form went smoothly, eventually new, technical problems arose while casting. Technical adjustments were necessary to the new form, and not all operators had learned the new work processes related to the operation of the new technology. During these months there was a lack of communication between Hycast and the cast house in Høyanger, as they had not agreed upon in advance how to solve issues emerging in later stages of the implementation. Many of the problems arising after the implementation of the new form happened as a result of the complexity of aligning the new form with the existing machinery:

To take a technology from a reference center and into a production facility creates a need for a lot of new thinking. You have to fit the new technology with the existing equipment, which differs greatly from the surroundings in the reference center. Therefore, these types of projects are more demanding than we think they are. I believe there is some learning here for us to take in, because it is not that often we introduce completely new technology.

Manager 3, Hycast

What Manager 3 from Hycast addresses, is that the implementation of a new technology into the production process is complex, as the technology must be aligned with the existing machinery. This existing machinery differs from the surroundings in a research facility, and



therefore one must expect that unforeseen problems might arise. Operator 1 also points out that the testing facility differed from the actual production, and that some of the parameter settings did not match the once they operated with in the reference center. But the main issue was related to the programming:

This is an automatic technology, and many of the aspects to consider when implementing it have evolved consecutively. It was a challenge to make the new equipment fit into the existing machinery. . . Hycast was lagging behind on the programming part. Perhaps they could have been better prepared. A lot of work was done during those two weeks of implementation of the form, but evidently one could have wished there had been better preparations.

Operator 1, Høyanger Cast House

His impression was that Hycast could have done more to prepare the technical aspects better in order to make the form fit with the existing system. Whether or not that is the case, what seems evident from the statements above, is that aligning new technologies with an already existing system is a complex process, which calls for extensive communication and follow-up in later stages. Some of the challenges one might be able to avoid with extensive preparations, but if changes are made on place in an interconnected production system, it might not be possible to predict all consequences in advance.

Unfortunately, the communication between the cast house in Høyanger and Hycast did not function optimal in the months after the implementation in February. During the spring of 2014 there was a fire in the cast house as a result of poor communication:

The communication dropped. Modifications were completed by them [Hycast] on the equipment here in the cast house, which had not been quality-checked. . . They had completed some programming on the equipment without cross-checking with our automation technicians, which had consequences. . . We then ended up having a fire in the cast house and the AFM casting form was damaged.

Area leader, Høyanger Cast House

This is only one perspective of the story, but both parties had the same understanding that there had been completed programming by representatives from Hycast on the equipment in Høyanger, and during this process the communication had been insufficient. The result was

that some aspects of the programming were not completed in an optimal way. Manager 3 from Hycast emphasizes that better communication could have hindered the accident, and that changes in routines for communication were changed in both Hycast and Høyanger cast houses after the accident.

Another challenge in the following months related to new work processes. The new technology required new skills of the operators. In learning them, the SOPs (Standard Operation Procedures) and other process management tool were broadly used, with success:

The SOPs are fundamental. We always have to use them for training. . . Otherwise there would be chaos; ‘What do I do?’, ‘What do you do?’ The SOPs give specific work to each person, so that your tasks do not mix up with others`. You know what to do.

Operator 3, Cast House, Høyanger

With the SOPs and other tools, the operators have a guide for how they can do things themselves, and are further trained in working systematically, which is an advantage:

For us it is important to have a well-functioning receiving system for our technologies. Our technologies are made in a way that creates a need for correct operation of it, and therefore it is very important to have operators doing the right things. I believe this is a lot easier if you have a culture, like they [Hydro] have with the AMBS, where the operators follow routines and always do things correct.

Manager 3, Hycast

Standardization and working systematically is above noted to be an important factor for successful technology implementation by the technology supplier. The operators emphasize that they have had to learn new work processes:

The new technology requires more competence. It is more computerized and has a need for more steering. The equipment is so precise and accurate that you have to know what you are doing. . . It is very fun, but at the same time very challenging.

Operator 3, Høyanger Cast House

The old and the new technology require two completely different working methods .The new technology requires very accurate temperature settings, and always hitting the right

temperature is very important, otherwise the metal will freeze during the filling-process. RTD assisted the cast house in developing the competence of the workers in the cast house. But operator 1 feels the management could have done more when it comes to making sure all operators were comfortable with the new equipment:

We quickly realized that here we needed to think a bit differently now than with the previous technology. That was the challenge for us. . . Every shift should have been properly trained. Here we faced a challenge, because it was voluntary to go to Sunndalsøra, and not all wanted go.

Operator 1, Høyanger Cast House

Operator 3 also emphasizes that there should have been more control over the training process, and that it should have been put up a real training plan. However, not everyone wanted to engage in learning the new technology:

I would say most people, perhaps 80%, thought this was very exciting and was in on it from the very first minute. But there was a small group, around 20% who would disappear if they were asked to join in on the learning.

Unit manager, Høyanger Cast House

What the unit manager is explaining is a resistance among some operators to learn the new technology. As not everyone had participated in the training in Sunndalsøra, some were therefore unsure of how to operate the new equipment. How can one ensure everyone has the necessary capabilities in operating a new technology? Interviews revealed that the management in Høyanger had people from RTD come and help train employees on the shifts in using the technology, but perhaps this should have been done more extensively? It seems this is an important area to devote focus when planning for the organization of innovation projects where the new technology calls for a set of new competencies.

In this project the operators in the cast house feel the sales department has been a bit too quick to approve products for sale. They highlight the fact that one cannot assume a new technology is ready for continuous full-scale production straight after its implementation:

The top-management should look at how they implement new technologies and what they can do better. More test-castings could have been done in RTD Sunndalsøra. The new products could have been casted there a sufficient amount

of times, so that they were certain that this is the way to do it, before they bring the new technology to us. Otherwise we have to do the test-castings simultaneously as serving other customers in Europe. . . That is just wrong.

Operator 1, Høyanger Cast House

He explains that operators become despaired when casting cracked blocks, and sees it as a waste of work. And although one may interpret this at first sight that the operators are not eager to cast test-products, this is not the case. As operator 2 explains, “We are more than happy to do test-casting if we have someone with us. Representatives from RTD Sunndalsøra could come down here with us. But it needs to be planned and added to our production-plan”. Apparently, the operators felt a bit left to themselves as they casted new, untested alloys with the new technology, which were supposed to be sold to market.

#### ***9.3.4 Follow up***

The cast house in Høyanger was not satisfied with the follow-up they received from Hycast after the initial implementation:

What we all agreed on here in the cast house, after Hycast had left and the first cast was completed, was that they should have been here to follow up, making sure the equipment worked properly in the subsequent stages as well. Perhaps they should have been here for three or four weeks to follow up on the programs, making sure they were all functioning properly. They should have been here to secure the equipment performed as specified, done fine-tuning and optimization.

Unit Manager, Høyanger Cast House

Luckily, representatives from RTD Sunndalsøra were present during most of the castings during the spring of 2014. Their presence was greatly appreciated, as they had knowledge about the new technology. Manager 1 from Hycast also address this matter, “On the pilot the cast house in Høyanger felt that we should have been more on site, and participated more. And I agree that we should have been more present and followed up the equipment more thoroughly”. He emphasizes that Hycast wants to meet the requirements of all their customers, but that sometimes they simply cannot manage due to shortage in staffing. Manager 2 from Hycast explains that from his point of view, misunderstandings related to follow-up often arise because the organizations have different roles in the project:

We are a supplier of technologies. What this means is that when the equipment is set up and functioning properly and meets the demands for guarantee, our job in the project is done. If the operations or cast house want further follow up, this becomes something close to an extra service.

Manager 2, Hycast

Manager 2 from Hycast further note that he understands that Høyanger would have liked more follow up. However, like Manager 1, he adds that Hycast were very busy at that time with several other large projects and did not have sufficient capacity. Without a doubt, both sides agree that these misunderstandings were closely linked to the way the project was set up, and that there was a lack of agreements addressing such issues in advance. To solve issues related to follow-up, both sides state that it needs to be addressed as early as during the project planning and contract agreement:

It is a matter of cost. Their hours are running. I believe it is important to have this specified in the contract, that we expect a certain follow-up after the initial technology implementation. Because this is something you often forget; the equipment starts, everything works, 'YES!', and then the people involved part from each other and start focusing on something else.

Unit manager, Høyanger Cast House

By agreeing on how to deal with arising obstacles prior to stable production such issues, one will assure a smoother implementation phase. When implementing new technologies, having suitable organizational structures for the project and risks ahead is thus emphasized as crucial. Proper preparation and agreement on follow-up can help save large costs:

There is continuous production and large costs involved. This might not always be evident, but starting up this kind of equipment with a few failed start-ups, is very expensive. A lot more expensive than people think. . . If you cast and do not get a proper start on the casted sheet ingot, several hours pass by before you can start casting another one.

Senior researcher, RTD

Despite the organizational and technical challenges related to follow-up, the interviews gave the impression that the project was completed with an overall satisfying result. Today the full-

scale implementation of the AFM-technology has started, and the interviews revealed that the experiences from the pilot were taken into account when planning and organizing for it.

#### ***9.4 Project success factors and challenges***

As this was a pilot project characterized by substantial technology development, there was a need for extensive coordination between the involved departments. However, the formal project management put the project off to a rough start. Both the cast house in Høyanger and Hycast noted that from the start there should have been a clearer project management in this pilot project, taking care of the communication and coordination between the departments and making sure the project progressed forward successfully.

Even with an absent project manager, Hycast and the cast house in Høyanger ensured project progress. The internal reference group put up in the cast house and the new informal structures that appeared were noted as success factors. The design reviews at Hycast were important for developing the technology, and the operator training was important for developing new competencies of the workers and engaging everyone in the project. Local expertise on the casting process and the attitude of the employees in the cast house were further noted as key success factors for this pilot project, as was systematic problem-solving using AMBS-tools.

However, there were several challenges brought up both prior and after the initial implementation of the form. The challenges related to; ensuring sufficient capabilities of all operators; communication and coordination between Hycast and the cast house; and alignment of the new equipment with the existing machinery. The involved departments had not agreed upon in advance how to handle potential problems after the initial implementation. It seems that Hycast and the cast house worked with slightly different premises and background thoughts for the project, and perhaps they should have been more aligned regarding the project's overall goals. The cast house in Høyanger was very focused on deadlines and progress, while Hycast was more in a place where they would be able to set up the equipment and have it tested. This eventually became a pressing issue for the cast house in Høyanger. Technical problems emerged in later stages, and solving these turned out being a challenge due to time constraints and insufficient knowledge about the new technology in the cast house.

This again highlights the importance of being able to contact the expert department after the initial implementation of a technology. Not only must the new technology be aligned with the existing system, which may create other problems in the production process, a production facility also greatly differs from a test-environment. What was emphasized by informants in this project was that the technology was not directly transferrable due to these differences.

The success factors and challenges of the project are summarized in the tables below:

<b>Project success factors:</b>	<b>Description:</b>
<b>Design reviews</b>	The opportunity for the cast house organization to participate in the designing of the new casting form at Hycast`s facilities in Sunndalsøra.
<b>Involvement and training in Sunndalsøra</b>	Organization of training sessions to learn the technology and possibility to participate in technology development.
<b>Operator attitude and curiosity</b>	The operator had a great willingness to learn about the new technology. They were passionate to learn more about their production process, and their positive attitudes and their motivation has been highlighted as a critical factor for the successful implementation.
<b>Informal new structures</b>	The local reference group set up by the unit manager delivered good results and made sure progress was made. New meeting structure .
<b>Interdepartmental cooperation</b>	Good cooperation between RTD and Høyanger throughout the project and during later stages.
<b>Local expertise</b>	Operators within the organization with extensive experience and knowledge of the casting process. Experienced operators themselves found ways to handle new, technical obstacles.
<b>Communication</b>	New meeting structure. Prior to, and following the initial implementation the internal project created an arena for meeting. They followed-up on activities, and created a sense of ownership.
<b>Successful construction period</b>	The two week period with site preparations was characterized by great efforts from both Hycast, RTD and the cast house.
<b>Systematic problem-solving using AMBS-tools</b>	Several AMBS-tools were used during the preparation phase, and also during the implementation phase. Standard Operation Procedures (SOP) for training operators in using the equipment in the first months. Usage of tools is a premise for conducting larger innovation projects.

*Table 9: Project success factors AFM project*

<b>Project challenges:</b>	<b>Description:</b>
<b>Resistance to learn the new technology</b>	Not all operators know the new technology, some did not participate in the training, others did not want to learn in the plant either.
<b>Formal project management</b>	The formal project manager evidently did not to a sufficient degree fulfill his responsibilities. Needs to be more 'Hands-on', dealing with communication, coordination related to technology improvement in various project stages, and aligning differing interests.
<b>Assurance of capabilities</b>	Apparatus for assuring necessary capabilities of all operators
<b>Test casting</b>	Organize for test casting of new alloys where management is present.
<b>Pilot-project organization</b>	Lack of available guide of how to organize pilot projects in Hydro.
<b>Communication</b>	The communication between Høyanger and Hycast was not sufficient. Might have hindered the fire. Linked to the lack of project management from the initial organization. Some felt the internal communication was insufficient
<b>Technical adjustments</b>	Challenges linked to aligning the technology with existing equipment.
<b>Follow-up</b>	Lack of follow-up by Hycast. Although the initial implementation is OK, new issues arise at later stages due to the complexities and interconnected production system.
<b>Time</b>	Long verification process

*Table 10: Project challenges AFM project*



# 10 Cross-case comparison

In this chapter, I will compare the findings from each of the three step-change innovation projects. More specifically, for the initiation phase and the implementation phase, I will identify elements that are similar to one another, and then outline the similarities for the overall innovation processes. Thereafter, a conceptual model for managing step-change innovation in process industries will be presented.

## *10.1 Project Initiation:*

The initiation phases of all three cases were characterized by similar elements. As the AFM project was a pilot for a much larger project, it differs somewhat from the two others projects. Not all cases are exemplified in the text under each element below, but all are included under each element in the summarizing table.

### *10.1.1 Problem-solving*

Problem-solving was at the heart of the initiation in each of the step-change innovation projects, and problems related to work environment and product-quality were reoccurring. In the emulsion project, work environment and concerns for product-quality led to an extensive trial and error process of production process improvement. In the anode recipe case, solving the issues related to the slot-cracks in the anodes was at the heart of the initiation. Prior to this, an extensive and systematic problem-solving process had been going on for years to better the performance of the anodes. In the AFM project, the new alloys called for a new casting technology, as the old technology did not deliver desirable results when casting complex alloys. Improvement of work environment was also a problem they solved with the new AFM technology. All these findings from the cases are compatible with Aylen's statement about innovation in process industries: "Innovation is driven by problem solving" (2013, p. 283), presented earlier. The "problemistic search" (Cyert & March, 1963), ultimately continuing as long as the problem remains to be solved. An important finding in this study is the evidence of how this problem-solving pattern is being managed by using various process management tools. Systematic working methods and problem-solving tools were emphasized by several interviewees as very helpful in the process towards finding the root cause of a problem.

Perspective, combined with a systematical problem-solving approach, seem to be two key elements related to initiating a step-change innovation project in the process industry. At

some time in all the three cases, it was found that a completely new direction was needed to solve the problems at hand. In the emulsion project, after having worked systematically together to find the root cause of the problem, they suspected that it would be a necessity to search for a completely new and different technology. In the anode recipe case, the unit tried various solutions to solve the slot-cracking problem, but without improvements to the crack related issues. The solutions they had been trying were all focusing on variation-minimization and were within the same technological trajectory. The governance manager then saw the problem from an overall perspective, and suspected where the solution might be found. An overall perspective of the current situation is necessary in order to know when you need to think differently about a problem and the solution. To have an organizational department, such as the PMS in the anode recipe case, might positively affect the initiation processes of step-change innovation projects.

### ***10.1.2 New Knowledge***

Once the cause of a problem is found and you suspect you need to change course, how do you find the competence and knowledge you need? In all three cases, expert knowledge from other departments has been crucial for the initiation of the projects:

- Wire rod: R&D Bonn and R&D Karmøy
- Anode recipe: the other Hydro plant, PMT, PMS
- AFM: Hycast and RTD Sunndalsøra

These departments helped develop the technical solutions needed. What is interesting though, is that in two of the cases (emulsion project and anode recipe) it was rather coincidence that key people knew where the necessary competence could be found. It seems that casual connections and weak ties play an important role, and this is an interesting finding of this study. This was also Granovetter's (1973) point. He emphasizes that strong ties (people you know well and see often) provide little new information to you. New information you often get from weak ties, such as acquaintances or friends of friends. What seems to be fair to conclude from this, is that step-change innovation projects requires competence outside the local unit, and therefore employees in different departments should somehow be familiar with where certain knowledge can be found within the company. Knowledge management seems to play a key role. These findings support activities such as cross-department rotation of managers and cross-plant workshops.

### ***10.1.3 Local Management***

In all three cases, the unit management played an important role during the initiation phase. The case analyses showed that once local management understands the potential benefits of undertaking a project, they must be willing to take the associated risks. However, innovative behavior and willingness to take risks might be affected by incentives. What are the incentives for managers for taking the financial risks of engaging in greater innovative projects? Innovation takes time and has unpredictable outcomes, while ongoing operations might be measured on short-term performance indicators. This may create a tension between short-term and long-term priorities for managers, which often are fundamental incompatibilities. To solve this tension, resources may play an important role. As Nohria and Gulati states, “In organizations that have little slack, managerial attention is likely to be focused first and foremost on short term performance issues rather than on more uncertain innovative projects” (1996, p. 1249). The possibility managers have to somehow come in contact with necessary resources to undertake step-change innovation projects therefore should be evaluated within an organization. As an example, in the anode recipe case, the project manager from PMT was considered an invaluable resource for the Sunndal Carbon organization in conducting the project, as well as the governance manager from PMS spent a crucial role as an extra resource helping initiate the project.

### ***10.1.4 Involvement and Organization***

In the initiation phases of the cases, involvement of employees has been important for several reasons, such as; getting the whole organization familiar with why initiatives for change are undertaken; secure motivation and engagement among employees; and access the competence and ideas of employees. Who to involve in the initiation phases depends on who sees the need for a step-change, and how large the scope of the step-change innovation project is. In all cases it was necessary to involve the local management by meetings and discussions, to make sure key employees were eager to initiate the project. The governance manager in the anode recipe case called this ‘the anchoring process’, and consisted of getting people on board. Later, the entire local organization needed to be involved. This was demonstrated, by many activities, such as communication and information about the project, meetings for problem-solving and delegation of responsibility. The operators in all cases emphasized that becoming involved in the projects from an early stage was very important for their motivation and engagement.

Project organization is a crucial element in the initiation phase, as it set the frame for how coordination, communication and project progress will evolve. The empirical findings showed that there were clear differences on this matter in the projects. The successful organization of the anode recipe project may be one of the main reasons why many of the challenges appearing in the emulsion project and the AFM project, were not mentioned in the anode recipe case. In particular, the project planning, time-constraints, communication, and project follow-up was eased due to the presence of the project manager. In the initiation phase, the element of properly setting up the organizational structure for the step-change project is crucial for the progress of the project and the overall project's success. The table below summarizes the elements of the initiation phases of the projects.

<b>Element:</b>	<b>Emulsion project</b>	<b>Anode recipe project</b>	<b>AFM project</b>
<b>Innovation driven by problem-solving</b>	-Product-quality -Process stability -Improve the work-environment	-Anode-quality -Process stability -Customer focus	-Increased capability to produce complex alloys. -Improve work-environment.
<b>Perspective</b>	-Problem-solving. -Seeing the whole picture and realizing a new direction is needed.	-Improvements achieved prior. -Finding the cracks and realizing a step-change is needed.	-Market study main reason for initiation. -Extensive development of technology for years.
<b>External competence</b>	R&D Bonn	PMS, PMT, other Hydro plant.	RTD, Hycast
<b>Local management</b>	-Willing to take risk -Willing to seek external help and ensure progress.	-Willing to take risk -Willing to accept external help.	-Willing to take risk -Taking the responsibility to ensure progress.
<b>Involvement of employees in local organization</b>	-Meeting structure -Delegation of responsibility within the cast house.	-Meeting structure -Communication and information flow	-Meeting structure -Delegation of responsibility in reference group
<b>Project organization</b>	-Project manager assigned, but he had also other tasks in production. No extra external resources contributed.	-A project manager solely dedicated to the project was appointed. -Came in as an extra resource to contribute.	-Project manager appointed, but did not prioritize the project. -Internal group set up, no extra external resources contributed.

*Table 11: Elements characterizing the initiation phase*

## ***10.2 Implementation success factors***

The elements ensuring implementation success were similar in the three cases investigated.

### ***10.2.1 Involvement***

Involvement has come in various means, from collective meetings and workshops, to delegation of responsibility and training. In the emulsion project, the type of involvement highlighted to positively affect the project's outcome was the delegation of responsibility and new work tasks given to employees. In the AFM project, the training of the operators in using the technology prior to its arrival was highlighted as the most important success factor in the pilot project by several. The participation in design reviews was also pointed out as positively affecting the engagement of workers in the cast house. As employees in various roles within a unit have different competencies, by involving representatives from different levels, a broader scope of viewpoints is taken into account, which has positive effects on the implementation phase. This was what happened in the anode recipe case, where the project manager stated that the operators taught her about the production process, and a mutual learning found place. Her presence in production and communication was greatly appreciated by the workers in the unit, and is another example of successful involvement of the local organization. As stated by Rao & Weintraub (2013), people often underestimate the importance of the people-oriented determinants of an innovative company culture. In this study, involvement was brought up by several informants, and I believe this highlights the importance of the people dimension when pursuing innovation. The findings indicating the importance of employee involvement are consistent with the results of Tjosvold (1998), when he found an indication that effective employee involvement was a critical mediating mechanism between people-oriented values and firm performance.

### ***10.2.2 Communication and Planning***

In all cases, communication stands out as a crucial element that must be planned for properly. The case analyses have shown that when working on a shift-arrangement, an even stronger focus needs to be given to both internal communication and communication with external people or departments. For internal communication, frequent meetings were put up to ensure information flow, and meetings were noted to be the best way to communicate in all cases. In the AFM project, the unit manager put up new, weekly meetings to ensure people followed up on their areas of responsibility. In the emulsion project, a new daily meeting was established by the unit manager for discussion and problem-solving. In the anode recipe project, the project manager emphasized that putting up meetings as the arena for discussion and

information flow was the main channel for communication. A general lack of time to read reports, combined with an opportunity to force people to take a standpoint in discussions, were some of the benefits of meetings mentioned. Besides meetings, the overall internal communication in the projects were OK, although there were a few workers in the emulsion project and the AFM project noting it could have been better.

Aylen (2013) argued that one of the solutions to the stretch paradox was to plan for process innovation in the same way as one plans for product innovation. I definitely found empirical evidence supporting this in the study. Operations are predictable, while innovation is uncertain. Therefore, in step-change innovation projects, one must think differently about planning compared to what the production unit does when it conducts routine projects for continuous improvement. In the anode recipe project, the project manager planned for the preparations and test-runs, for unforeseen events, and the phases after full-scale implementation. This was clearly one of the success factors of the project. The project manager had planned for things not going according to plan. In the other two projects, the site preparations and initial implementation was also greatly planned, however, planning of follow-up during the later phases was insufficient.

### ***10.2.3 Precision Culture***

Process control and process management tools played an important role during the implementing phase. Process management tools were used for systematic problem-solving, ensuring development of competence and smooth implementation process. Working systematically with problem-solving and operational improvement helped the units tackle the new operational problems in the production processes. For example, in the AFM project, various tools were used to help prioritize tasks and to record process changes after changes had been made. The unit manager in Høyanger emphasized, that the more facts and numbers you can put on the table, the more certain you will be on which decision to make. Further, in the AFM case it was stated from Hycast that a well-functioning receiving system was a premise for the implementation of their technologies. These two aspects were emphasized as important in the two other cases as well. One important aspect is the need for process stability and control, in order to clearly see the changes in parameters after adjustments have been made. How will you know what is causing your *new variation* if the production process is not under complete control?

### 10.2.4 Local Expertise

Due to complex linkages between the stages in the production processes, local expertise has proven to ensure project progress and to ease the technology implementation. In the anode recipe case, the project manager used the local expertise to learn more about the production process. Local expertise can also help smooth the process of realigning the new technology with the existing system, as potential technical challenges can be identified by employees who know the process. This was the idea behind the design reviews in the AFM project where input from the cast house was taken into account by Hycast to optimize the performance of the technology. Further, as everything is interconnected, knowledge of the old was crucial for solving problems caused by the new technology in the wire rod emulsion project. As R&D Bonn could not find solutions to the new operational problems, the workers in the wire rod unit solved the new problems based on the expertise they had of the existing system and process. The success factors for the implementation are summarized in the table below:

<b>Implementation</b>	<b>Emulsion project</b>	<b>Anode recipe project</b>	<b>AFM project</b>
<b>Success Factors:</b>			
<b>Involvement of local organization</b>	-The unit manager delegated responsibility to employees in the cast house, this ensured ownership.	-The project manager involved the local organization. -Creating motivation for the project.	-Training in using the new technology. -New meeting structure. -Delegating responsibility.
<b>Meetings: internal communication</b>	-Workshops. -New daily meeting where the unit could discuss issues.	-Workshops conducted by the governance manager. -Meeting structure.	-New, weekly meeting with representatives from all involved parties. Workshops.
<b>Planning of implementation</b>	-The initial phase well planned with good cooperation. However, the follow-up phase was not.	-Well planned. -Good cooperation between all parties during tests and full-scale implementation.	-The initial implementation and construction period well planned, not the follow-up phase.
<b>Precision Culture – Process Management Tools</b>	-Various AMBS-tools used for problem-solving. -AMBS-meeting structure. -Activity logs.	-AMBS tools and working systematically. -Being able to see the effects of changing parameters. Stable production.	-AMBS- tool for systematic problem-solving. -AMBS meeting structure. -Activity logs
<b>Local expertise</b>	-Local expertise in the cast house solved the technical challenges.	-Local expertise allowed for mutual learning.	-Local expertise handled the new operational challenges
<b>Case Specific Success Factors:</b>	-Visible leadership -Failure OK	-Parallel mill -Information flow -Follow-up	-Training -Local reference group set up by unit manager.

Table 12: Success factors of the implementation phase

## ***10.3 Elements causing implementation challenges***

What is interesting about the implementation phases, are the similarities of the challenges arising after the initial implementation of the new technology into the production system. Innovation is a process, and although idea generation and technology development are critical activities, the complexity of the implementation phase should not be underestimated.

### ***10.3.1 Skepticism***

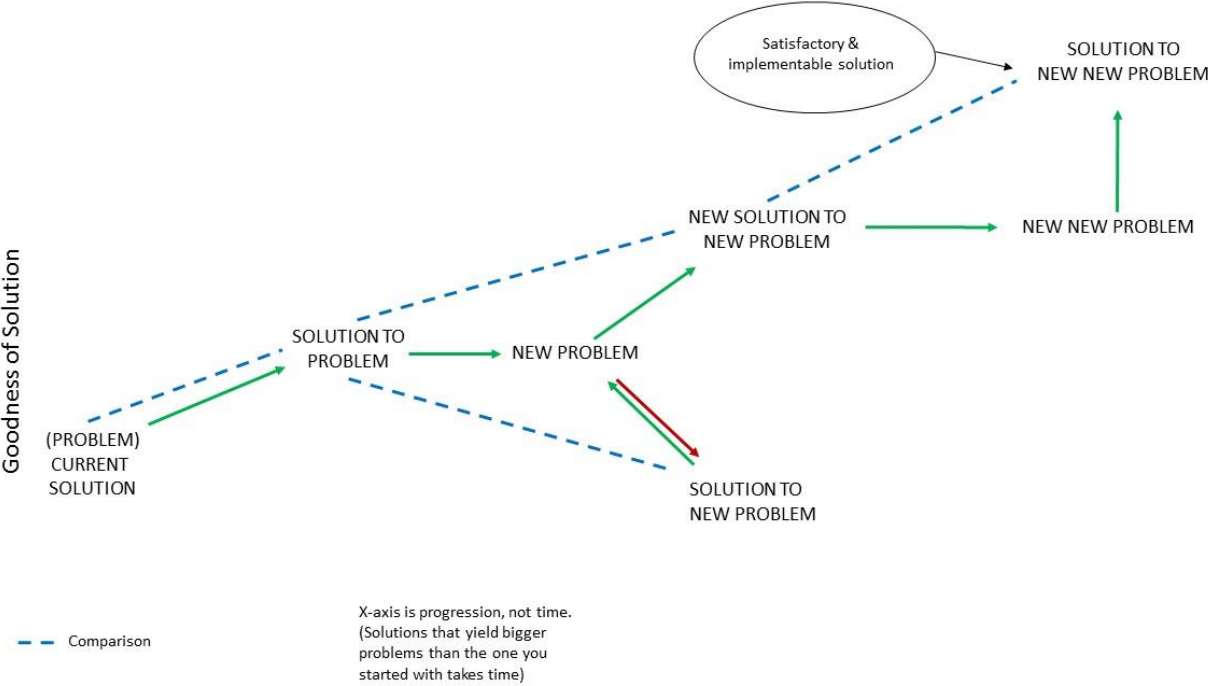
Not everyone is eager to learn a new technology, and skepticism among employees was present in all three projects. Fear of losing face, a lack of personal motivation or a lack of faith in the new technology, were potential reasons for skepticism mentioned by informants. A situation from the AFM project will serve as a good example for why skepticism must be dealt with prior to implementation: Everyone were given the opportunity to attend the organized trips to Sunndalsøra for training in using the new AFM technology, yet several did not attend. The implication of this was that not all operators knew how to operate the new equipment once it had been implemented. Evidently, these employees will not be able to help solve problems emerging in later stages after the implementation, or able to contribute to further improving the new technology.

### ***10.3.2 Realignment with current Machinery***

Consistent with the statements of Thomas Lager (2011), the case studies have shown that you cannot develop new products or innovate in parts of your process without an understanding of the entire production process. The interconnected and complex production process is optimized to fit the current product and the linkages between different stages and equipment means that improvements or modifications done in one part, will affect other parts. When a new technology is aligned to fit the existing production process, parameters and settings on the already existing system are often changed or modified. This may cause new problems in the production process. This pattern was found in all three cases. In the emulsion project, the old emulsion was the root cause of several production process problems. After the full-scale implementation of the new emulsion the initial problems disappeared, however, after a few months new operational problems appeared. For several months they tried solving the new problems caused by the solution to the first problem. Eventually they succeeded, but this was a comprehensive trial and error process. In the anode recipe case, the problems related to slot-cracks in the anodes disappeared once the new recipe was implemented, but new issues related to balancing the flow of materials emerged. This characteristic pattern of new



problems emerging after the implementation of a technology must be taken into account during a project planning phase of step-change innovation projects. The pattern put certain demands on the project`s organizational structure and to the follow-up required. The figure below illustrates the pattern found in the three cases:



*Figure 11: Achieving a satisfactory & implementable solution*  
*The y-axis illustrates the Goodness of Solution, and the x-axis progress.*

As everything is interconnected, the solution to the current situation (‘solution to problem’ in figure 11), creates a new problem. When solving this new problem, you might become worse off than you originally were, and choose to go back to solve the new problem. Then the new question becomes; do you find a solution to the new problem again, or do you go back and find a solution to the original one? To evaluate whether to solve a new problem, or to go back and solve the previous one, sufficient knowledge of the production process, the existing machinery, the old technology and the new technology, is necessary. This puts certain demands on the people managing the project; they must have sufficient knowledge about the entire process in order to make wise decisions on whether to continue with the new or go back to the old technology. The problems might differ in cost of solving, time needed to solve it, and the amount of external knowledge needed to solve it. At last, you will end up with a

satisficing solution. This solution will eventually become the object of stretch and incremental fine-tuning in the production process.

The pattern of a continuous stream of new problems emerging after solutions to the initial ones were solved, was a very important finding in this study, as this phenomenon ultimately affects the optimal organization and planning of step-change innovation projects. In particular, this pattern creates a need for extra resources, follow-up by the expert department and a ‘hands on’ project management. I acknowledge that this pattern might also arise when implementing incremental innovations in the production process, however, the competence needed to solve the new problems in step-change innovation projects is different. The complexity of the new problems emerging in step-change innovation projects will create a greater demand for new knowledge and coordination between departments than the problems occurring when pursuing incremental innovations.

### ***10.3.3 Resource Constraints***

Delivering excellent performance while conducting step-change innovation activities will be challenging if a focus on efficiency and cost-cutting strips an organization for any extra resources it might need for an innovation project. What we have seen in the three cases is that the daily operation and continuous production complicates the possibilities for the operations unit to maintain the flexibility required for conducting ambiguous innovation projects. In the anode recipe project, test-runs could not be started when originally planned, due to unforeseen daily operational problems in production. In the emulsion project, R&D Bonn emphasized that the cast house were too busy to deal with the problems as they emerged, and that the project manager had too many other things to do. In the AFM project, the unit manager emphasizes that there is always a time constraint out in production, and as the formal project manager was absent during the project, the cast house faced some hectic months while conducting the pilot project. There was a need for extra resources. In the emulsion project and AFM project, extra resources to help ensuring progress, follow-up, and taking care of communication and information flow between the involved parties would have been beneficial. Conducting larger innovation projects while simultaneously maintaining continuous production has proven to create challenges related to a lack of sufficient resources. This is consistent with Govindarajan and Trimble (2010a), who claim that business organizations are built for efficiency, and not innovation. “Unfortunately it is very easy to overestimate what the Performance Engine is capable of. Rare is the company that assigns too little to it” (Govindarajan & Trimble, 2010a, p. 30). The main issues were time and staff

shortage. What scope and complexity of an innovative project can a production unit conduct, before assistance is needed? The initial implementation went fine in all three cases, but it was during the later stages the resource constraints became an issue. In the anode recipe case, shortage of time and resources were hardly mentioned in the interviews, and all seemed pleased with the communication. Here the project manager came in as an extra resource, with sufficient time and capacity, which was greatly appreciated by the unit.

#### ***10.3.4 Information***

Communication internally and between different departments and externals was proven challenging in the projects. In the emulsion project, the geographical distance between Karmøy and R&D Bonn created severe communication difficulties. Providing detailed explanations of the new operating problems over phone was difficult. Further, they were filing a patent on the technology, which can be a very difficult in process-related industries (Schmidt, 2013), and this further complicated the information flow. In the AFM case, when problems arose in later stages, communication between Hycast, RTD and the cast house in Høyanger became a problem. In the anode recipe case, it was obvious that the project manager helped solve this problem with being very proactive, present and ‘hands on’ in her working method. She was communicating with externals (such as the electrolysis), and was out in production talking with the operators. Particularly the fact that she was out talking to every single shift was important for the communication part, as not everyone has the opportunity to attend all information meetings. What further complicates the issues elaborated on above is the long and time-consuming verification process. In the anode recipe project, it took four months until all the anodes had been approved by Sunndal Electrolysis. Similar, in the emulsion project and AFM project, it took several months until the customers had approved the products produced with the new production process technology.

#### ***10.3.5 Follow-up***

In all projects there has been a substantial need for follow-up by the expert department or the technology supplier after the initial implementation. Lack of follow-up after implementation became a severe problem in the emulsion project and the AFM project. The technologies implemented in the production processes did not perform as desired, which caused a need for frequent contact with the expert departments after implementation. This had not been agreed upon in advance, which became problematic in both projects when new technical problems arose. This was not an issue in the anode recipe project. New technical issues arose after implementing the new technology in this project as well, but the project manager was still

available for Sunndal Carbon to contact. Therefore, the employees in Sunndal Carbon did not experience a lack of follow-up. The differences between the projects indicate that when managing a step-change innovation project in process industries, ensuring proper follow-up after implementation is important. There will be necessary to handle adjustments and modifications, as one cannot assume the technology is directly transferrable from a testing-facility or research department. The contexts differ. The existing machinery will be affected by the new process technology, as well as the existing machinery affects the new process technology itself. There are several reasons for this; the complexities and interconnectedness of the existing machinery; and the difference between a testing-facility and actual production system. New problems might not reveal themselves until several months have passed, which complicates this challenge. One must therefore ensure that the knowledge about the new is not lost until the process again is completely stable, or the local unit has gained sufficient knowledge about the new technology. This must be taken into account when planning the step-change innovation project; Who will have which areas of responsibility during the later stages? Can we still contact the exert department? Such matters must be specified in the contract. The implementation challenges are summarized in the table below:

<b>Implementation Challenges:</b>	<b>Emulsion project</b>	<b>Anode recipe project</b>	<b>AFM project</b>
<b>Skepticism</b>	-The operators were skeptical of the new technology. -Lack of faith.	-Some did not believe the new recipe would ever work in Sunndal Carbon.	-Some operators did not want to participate in the trainings in Sunndalsøra.
<b>Solving one problem, but creating a new:</b>	-New technical problems caused by the new emulsion.	-New problems with capacity constraints and material flow.	-New technical problems related to programming.
<b>Resource constraints (continuous production)</b>	-Continuous production while new operational problems continued.	-Operational obstacles not related to the test-runs postponed the tests.	-Absent project manager. -Continuous production.
<b>Information flow</b>	-Working shifts complicated information flow. -Patent-filing. -Geographical distance to R&D Bonn.	-Not a challenge.	-Working shifts complicated information flow. -Lack of communication between departments.
<b>Time consuming product verification</b>	-Customer approval	-Customer approval	-Customer approval
<b>Lack of follow-up</b>	-From R&D Bonn	-Not a challenge.	-From Hycast
<b>Case Specific Challenges</b>	-Secrecy: they were filing a patent.	-Old production technology.	-Absent project manager.

*Table 13: Challenges in the implementation phase*

## 10.4 Managing step-change innovation

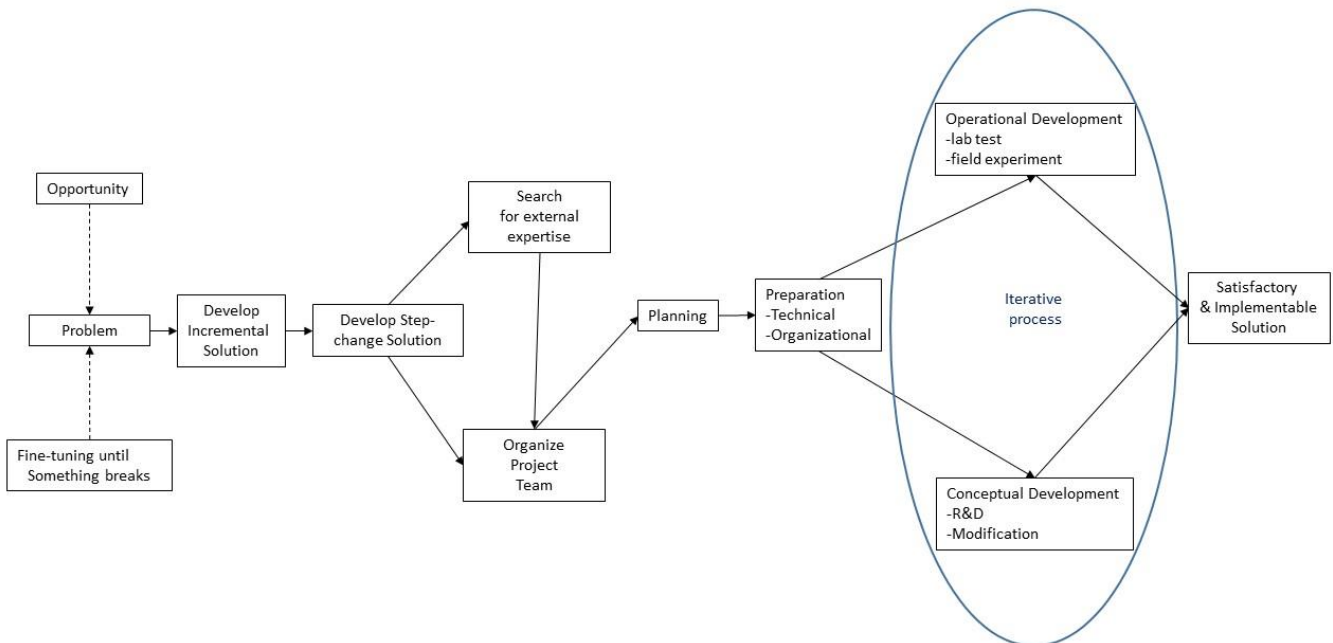


Figure 12: Conceptual model for managing step-change innovation

The findings in the case analyses and the cross-case comparison have been summarized in a conceptual model for managing step-change innovation in the process industry, as presented above. At first, a ‘problem’ arises in production, either as a result of incremental fine-tuning of existing machinery in the production process (fine-tuning until something breaks), or because an external opportunity cannot be pursued with the current solution. If efforts characterized by incremental improvements do not lead to further improvements of the current situation, one acknowledges that a step-change is needed. To develop a solution, an expert department is needed and a suitable project team must be put up. Ideally, this project team consists of employees from an expert department who will work in a partnership with the operations unit. Extensive planning is needed, as are the preparations needed for the technology implementation to come. There will follow an iterative process of conceptual development of a technical solution, happening in parallel as trials and testing activities explore the effects of the new technology on the production process. Once implemented however, this iterative process will continue, as modifications to the new technology will be needed. The ‘iterative loop’ in *Figure 12* above, is based on the model presented in *Figure 11*.

At last, a satisfactory and implementable solution is obtained, which again will become the new object of fine-tuning and ‘stretch’.

By investigating the model for managing step-change innovation presented above, and the results from the cross-case comparison, one can say something about how you can combine organizational structures for managing step-change innovation activities, with the structures needed for continuous improvement and operational efficiency. First, in the initiation phase, in order to either grasp the external opportunity, or solve the internal problem, someone with sufficient authority must ensure focus is put on the matter, and dedicate resources to pursue a solution. Who should this be? We have seen examples of both local management, and externals to the production unit, initiating the projects. Second, results of this study indicate that one should organize for a partnership between the operations unit, the project management and the expert department. There was one striking difference in the cases; in the anode recipe case, the project manager from PMT had been assigned with sufficient amount of time to spend on the innovation initiative. As the work of the step-change innovation project must flow in parallel with continuous production, extra resources to carry out the project and a clear division of labor might be necessary. Due to the planning and communication required, coordination between departments, and the complexities of the problems emerging, there seems to be a need to custom-build a portion of the team working solely on the step-change project, taking the project through all its phases. This might be someone from an external department, as long as the person has dedicated sufficient time for the project and are present.

One may wonder though, if the elements presented are criteria for successful step-change innovation projects in process industries, or simply just criteria for good project management? What is evident, is that successful step-change innovation projects require a ‘hands on’ project management to steer the project through all of the project’s phases.

# 11 Conclusion

The ultimate goal of this thesis has been to contribute to the academic literature by providing insight on how to manage step-change innovation projects in the process industry. Initiation of step-change innovation in process industries has proven to be a complex matter. The step-change innovation projects investigated in this study were driven by problem-solving. Operational problems arising from bottlenecks in production or issues related to work-environment, initiated searches for better solutions to the current situation. Once it is acknowledged that a step-change is necessary, finding the expertise needed to solve the problem at hand becomes the next step. However, first the local management must be willing to take necessary risks and invest time and resources in the innovative activities.

Extensive preparations, communication and information flow proved to be key success factors for the implementation phase. However, although the initial implementation of a new process technology goes smoothly, new technical problems most likely will emerge later. Aligning a new process technology with an existing machinery to solve an operational problem proved to cause new problems in the production process in later stages. In step-change innovation projects in process industries, the technologies implemented in one portion of the system will affect other parts of the complex interconnected production process. Therefore, one must plan and organize the step-change innovation projects in a way that enable follow-up by the expert department, and allows for technical adjustments and modification in later stages. Further, having a team or person, dedicated to the project and taking it through all its phases proved to ease several challenges.

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# Appendix

## *Interview List*

### *Wire Rod Case*

<b>Department:</b>	<b>Interviewee:</b>	<b>Interview conducted:</b>
Wire Rod Cast House	Unit manager	1xPhone 1xKarmøy*
Wire Rod Cast House	Process specialist 1	Karmøy*
Wire Rod Cast House	Process specialist 2	Karmøy*
Wire Rod Cast House	Operator 1	Karmøy*
Wire Rod Cast House	Operator 2	Karmøy
Wire Rod Cast House	Operator 3	Karmøy
Wire Rod Cast House	Operator 4	Karmøy
Karmøy Administration	Purchasing manager	Phone *
R&D Bonn	Senior researcher	Phone*
R&D Karmøy	Project manager	Phone*

### *AFM Case*

<b>Department:</b>	<b>Interviewee:</b>	<b>Interview conducted:</b>
Høyanger Cast House	Unit manager	Høyanger
Høyanger Cast House	Area leader	Høyanger
Høyanger Cast House	Safety representative	Høyanger
Høyanger Cast House	Operator 1	Høyanger
Høyanger Cast House	Operator 2	Høyanger
Høyanger Cast House	Operator 3	Høyanger
Hycast	Manager 1	Sunndalsøra
Hycast	Manager 2	Sunndalsøra
Hycast	Manager 3	Sunndalsøra
RTD Sunndalsøra	Senior researcher	Phone

### *Anode Recipe Case*

<b>Department:</b>	<b>Interviewee:</b>	<b>Interview conducted:</b>
Sunndal Carbon	Unit manager	Sunndalsøra
Sunndal Carbon	Area leader	Sunndalsøra
Sunndal Carbon	Process specialist 1	Sunndalsøra
Sunndal Carbon	Process specialist 2	Sunndalsøra
Sunndal Carbon	Operator 1	Sunndalsøra
PMT	Project manager	Sunndalsøra
PMS	Governance manager	Oslo
Sunndal Electrolysis	Process specialist Electrolysis	Sunndalsøra

\*) Interviews conducted by other NTNU students.

## A taxonomy of Stretch (Aylen, 2013, p. 274)

*Jonathan Aylen*

Table 1. A taxonomy of stretch

Dimension	Characteristics	Impact
Management and operator skill		
1. Pure learning	Operating experience	Enhanced throughput when operating and wider product range
2. Changes in maintenance	Mostly experience, better monitoring and scheduling	Shorter downtime, enhanced plant availability and better product quality
Embodied in extra capital		
3. 'Bolt-on goodies'	Additional modules of equipment (e.g. instruments and controls)	Higher output, better quality and reduced downtime
4. Reconstruction of existing equipment	Replacement and upgrading of core facilities (e.g. furnaces and motors)	Often higher output through removing bottlenecks
System-wide improvement – upstream		
5. Better availability of feedstock	Better scheduling of materials supply, more consistent supply	More regular operation
6. New feedstocks	New materials, different dimensions	Higher yield and heavier piece weights
System-wide improvement – downstream		
7. Better 'take' of materials	Better scheduling, warehousing and product logistics	Longer production runs
8. New capabilities	Larger capacity items for downstream processing	Higher yield and heavier piece weights
New products		
9. New qualities	Improved quality of existing products	e.g. Better surface finish, gauge, shape and dimensional accuracy
10. New products	Complete new products	e.g. High-strength low-alloy steels, transformation-induced plasticity steels