Journal of Cleaner Production 118 (2016) 65–77

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

# Kalundborg Symbiosis: fostering progressive innovation in environmental networks

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ARTICLE INFO

*Article history:*
Received 23 March 2015
Received in revised form
13 October 2015
Accepted 24 January 2016
Available online 4 February 2016

*Keywords:*
Environmental networks
Innovation
Sustainable development

ABSTRACT

Many environmental networks form around specific initiatives with prescribed outcome objectives. When the objectives are met, the networks frequently disband. Technological transfer halts and the social capital built up during the initiative fragments, in many cases, disappearing altogether. In an era of globally unsustainable economic activity, encouraging progressive innovation and broadening the scale and scope of knowledge transfer is one strategy for helping to attenuate ecological damage. This paper presents empirical field work which explores the Kalundborg Symbiosis in Denmark – a network of economic actors that has organically come together to implement industrial ecology principles – and documents how this network has managed to foster progressive innovation. The four drivers which emerged as central for fostering collaboration are i) a pragmatic environmental mindset, ii) the existence of opportunities to explore possibilities, iii) mutually beneficial initiatives and iv) the presence of dominant needs which stimulate a proactive search for solutions. The paper also contributes to sustainable public policy and urban planning literature by considering how municipal involvement can foster progressive and sustained development within the Kalundborg Symbiosis.



## 1. Introduction

Jeffery Sachs, the head of Columbia University's Earth Institute succinctly summed up the ecological governance challenge that humanity faces: “We are not on a course of sustainable development. We're not even close” (Sachs, 2007). Many course adjustments will have to be made to return to a sustainable trajectory. On the resource conservation front, two strategic necessities include the imperative to collaboratively innovate in order to improve the utilization of resources (Hall et al., 2013) and to nurture the “relational capital” needed to evolve and share innovative practices with the widest possible audience (Pike et al., 2005). In short, we need to develop *sustainable* systems of collaboration.

Sustainable collaboration is not currently the norm. Most alliances that aim to enhance environmental governance are project-based initiatives – goals for the initiative are set, timelines are established, and responsibilities are defined. When the goals are achieved, the stakeholders shake hands and part ways. Although laudable, project-based environmental initiatives are suboptimal in that effective working relationships that are honed through time and effort during the project are severed with the dissolution of the project. Moreover, the momentum that can extend from goodwill and the experiences gained by learning through collaboration (Perz et al., 2010) cease as soon as the project concludes. In a world where we are not “even close” to a sustainable development trajectory, it is imperative to find ways to optimize environmental collaborations because this amplifies results (Albino et al., 2012). As Lambert and Boons (2002) put it, “incremental change should lead to system changes rather than system optimization”. One aspect of this challenge is to identify strategies to sustain relationships beyond projects that terminate, leading to a disbanding of the collaboration.

This paper attempts to contribute to this area of enquiry by exploring the Kalundborg Symbiosis (hereafter “KS”), a unique example of organically-evolving, self-sustaining environmental collaboration in Denmark. The term “organically-evolving” has been used in reference to the KS because it is a network of private and public entities that began with a couple of collaborative initiatives between a few organizations and has subsequently expanded in scope and scale of participants over time. As Hans Berndt Jespersen, one of the early participants explained in an

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http://dx.doi.org/10.1016/j.jclepro.2016.01.061
0959-6526/

interview, "*it started as a non-project developed by a non-organization*".

The KS began with collaborative agreements between a few industrial concerns to share a key resource (water) and take advantage of waste resources (heat, steam and gas). Subsequently, for some of the firms, the collaborations have deepened with firms exploiting new opportunities for initiating closed loop collaborative practices. Additionally, new firms have joined the KS over time and the exchange of resource and waste flows has expanded. Until recently, all of this has been achieved without the benefit of a central coordinating authority. The Kalundborg Symbiosis then, is one of the few examples in the world of an organically-evolving network of strategically unassociated economic entities that continue to collaborate in order to improve utilization of resources and share knowledge. This unique network, which has been in existence for over 40 years, can potentially yield valuable insights into the processes that encourage environmental networks to transition from one-off cooperative ventures to sustainable collaborative relationships.

There are two key contributions that this study aims to make. First, by documenting the evolution of relationships within the KS and attempting to explicate drivers that foster sustainable collaboration, this paper hopes to contribute process insights to improve environmental collaborations. Second, since there is a notable lacuna on how progressive innovation is fostered between collaborating entities (Patala et al., 2014), there is by logical extension a shortage of insight into how policymakers can effectively foster progressive collaborations to improve environmental governance in a given community (Jiao and Boons, 2014). Since, as van Beers et al. (2009) have argued, support policies for industrial symbiosis initiatives tend to be context specific, the main contribution of these policy insights will be most relevant to policymakers in Kalundborg. However, it is hoped that the policy lessons from Kalundborg will be as relevant to sustainable urban development theorists, as the story of the Kalundborg Symbiosis has been in supporting the inception of industrial ecology theory.

This paper is structured in the following manner. Section 2 will conceptually position the research by reviewing the existing literature that centers on factors which enhance collaboration within diverse multi-stakeholder groups. Section 3 will introduce the grounded theory, case study methodology that was adopted for the fieldwork underpinning this analysis. Section 4 will summarize the evolution of the KS. Section 5 will discuss the key factors which have fostered progressive collaboration in the KS, as derived from interviews with leading executives, who work with the firms that participate in the KS. Section 6 will consider the government's role in supporting progressive evolution within the KS. Section 7 considers two limitations to the study and provides concluding comments.

## 2. Literature review

Prior to undertaking the fieldwork for this study, a literature review was conducted in order to try to gain insight into factors that other researchers have identified as being instrumental in fostering collaboration in environmental networks. The intent was not to produce an exhaustive list of influential factors, but rather, to cultivate a foundation of knowledge for operationalizing the field study (Fiedler and Deegan, 2007). This is because the implementation of a grounded theory research methodology requires the researcher to enter into fieldwork with sufficient knowledge of the phenomenon being studied to enable generation of "scoping questions" which are instrumental for defining the boundaries for phenomenological observation (Charmaz, 2006).

It is worth noting that of the two dozen or so articles which were extracted from Science Direct using the keywords *environmental network* and *collaboration*, none of them dealt with the topic of network sustainability. The majority of these studies focused on corporate alliances, networks involving corporate and non-corporate stakeholders or supply-chain alliances, the latter receiving by far the most attention.

All of the articles examined, including the ones which centered on pitfalls of collaboration, were in agreement – collaboration on environmental issues leads to more positive results. Perz et al. (2010) referred to a collaborative advantage, wherein firms combine knowledge and competencies to be more efficient in addressing environmental issues. Albino and colleagues concurred adding that, particularly for smaller firms, addressing environmental issues alone might wind up being "too costly, inefficient and time-consuming" (Albino et al., 2012). In short, there appears to be widespread agreement that overall, collaboration is a desirable approach to improving environmental governance; but, what supports effective environmental collaborations?

Research that focuses on corporate alliances tends to acknowledge that the existence of common goals can significantly improve collaborative effectiveness (Nidumolu et al., 2014). Other researchers have added that common goals need not be of an economic nature, successful collaborations can also form around the need to confront a "common enemy" (Lashley and Taylor, 2010). This suggests that the notion of a common goal could actually be manufactured in order to empower collaboration amongst diverse stakeholders. Lashley and Taylor (2010) refer to this as creating a master frame. They argue that the ability to identify with an issue is a key factor for mobilizing collaboration.

Other research suggests that stakeholders enter into collaborations for various strategic reasons; and as long as these strategic needs are met, the collaboration will continue to be successful. In a meta-study that attempted to document the theoretical perspectives underpinning the strategic choice to collaborate, Fiedler and Deegan (2007) identified eight dominant rationales. These included: i) collaborating to increase the participating firms' chances of survival, ii) collaborating to procure essential scarce resources from the other party, iii) collaborating because of pressure from external institutions (i.e. government mandates) to conform to particular rules or norms, iv) collaborating in order to gain legitimacy, v) collaborating with other organizations to create a power shift in favor of the allied organizations, vi) collaborating to attract key resources that are necessary to gain a competitive advantage, vii) collaborating to satisfy the expectations of shareholder groups, and viii) collaborating to reduce costs. In looking for a common unifying force, the authors of this study concluded that collaboration can be considered to be an "adaptive response to environmental uncertainty" (Fiedler and Deegan, 2007).

Yet another group of researchers concluded that access to resources was an enabling factor of successful collaborations (Zhang and Wang, 2014). Although the research was centered around collaboration in regard to carbon dioxide emission reduction, the conclusion of Zhang and Wang (2014) was that the lack of adequate infrastructure and facilitation mechanisms represented the main barriers to collaborative success. Intuitively, it makes sense that financial capacity, infrastructure and government support represent features that might help enhance the success of collaborations; however, there are also numerous examples of collaborations that have been underfinanced and unsupported by the government. Therefore, it is dubious as to whether these findings represent necessary conditions, let alone sufficient conditions for collaborative success.

Perhaps the dominant characteristic that emerged in the literature as being instrumental in supporting successful collaboration

was the existence of elevated levels of "social capital" (Pike et al., 2005). Although some researchers framed this using different terms such as trust (Wondolleck and Yaffee, 2000) or willingness to lead (Perz et al., 2010) or tight social networks (Wyborn and Bixler, 2013), the tenet that relationships underpin collaborative success appeared in a great many studies.

Another vein of research explored the makeup of collaborations, arguing that not all collaborations are the same and these differences impact the type of factors which foster collaborative success. Lashley and Taylor (2010) view collaborations as cooperative engagements that exist on a spectrum. These can range from jointly planned projects to separate projects that are somehow coordinated. They further point out that collaboration can be as simple as sharing information or exchanging insights on tactics and strategies. Given that each of these different types of collaborations entails different levels of risk, complexity, commitment, interaction and resourcing, it would not be surprising to discover that different manifestations of collaborative engagement possess different requirements for success.

Indeed, one of the differences that have been shown to impact the nature of a collaboration is philosophy. Research by Comi et al. (2015) introduced the concept of "ecophilosophy", which the authors define as the worldviews that stakeholders possess when entering into a collaborative relationship. These authors argue that one's perspective on the human–environmental relationship significantly influences the selection of collaborative strategies. This suggests that both collaborative strategy and ultimate effectiveness depend significantly on the philosophical makeup of the stakeholders involved.

The notion that structure and stakeholder makeup predetermine the types of factors that go into supporting an effective collaboration implies that diverse multi-stakeholder networks such as the KS can be prone to conflict. As Perz and colleagues summarize, "*different types of organizations have distinct structures, goals and priorities, which complicates collaboration among organizational types*" (Perz et al., 2010).

All of these insights formed the conceptual foundation for employing the grounded theory methodology, which will be described in the next section. When entering into the field, these fundamental insights focused research attention on identifying shared goals, trying to assess which of Fiedler and Deegan's eight rationales for collaboration applied to the Kalundborg Symbiosis, assessing the extent to which infrastructure and government support influence the efficacy of the KS and investigating how the stakeholders within the collaborative network view and value the collaboration. These themes formed the scoping questions which, together with the overarching research question of "what supports progressively evolving, sustainable environmental collaborations?", formed the initial blueprint for operationalizing the methodology that is described next.

## 3. Methodology

To reiterate a fundamental point that guided the selection of methodology, there is a dearth of prescriptive research that identifies factors that lead to the success of *sustainable* collaborative networks. There was a wealth of analysis concerning collaborative networks that form for a given project or for a specific strategic goal; but there was a shortage of inquiry into what makes organically-evolving networks such as the one exhibited in Kalundborg successful. Perhaps the most substantive of these studies was the work done by Lambert and Boons (2002) who argue that eco-industrial activities should be planned in a more strategic manner by focusing on mapping resources flows and exploiting synergies. However, the authors ignored the interrelationships between the parties. Moreover, they failed to put forth substantive recommendations on how this could be operationalized when, as even the authors acknowledge, willingness to collaborate is frequently driven by economic benefit which tends to diminish over time. Therefore, the goal of this study was to uncover greater insights about the drivers underpinning collaboration in order to support recommendations for encouraging more sustainable economic activities in a given community.

Grounded theory is known as a methodology for facilitating the kind of discovery sought after in this study (Glaser and Strauss, 1967). It is an inductive, qualitative approach that is highly suited to situations where existing theories do not exist. Not only does grounded theory allow the researcher to identify variables and relationships that influence the target of study, it is also typically supported through an unstructured interview process that, if implemented in a competent manner, can yield rich insights, which are instrumental to creating useful theoretical constructs (Dyer and Wilkins, 1991; Eisenhardt, 1991).

In grounded theory, the process of discovery is operationalized through an iterative process that begins with scoping questions, as discussed in the last section. These questions serve as initial frames for guiding the inquiry process (Charmaz, 2006). In the case of the KS, the scoping questions in general and the overarching research question (What supports progressively evolving, sustainable environmental collaborations?) formed the foundation of inquiry for the first semi-structured interviews conducted with key KS stakeholders. This approach was not dissimilar to the interview strategy adopted by Fiedler and Deegan (2007) in their enquiry into determinants of environmental collaborations.

In grounded theory, as the inquiry progresses and the researcher gains new insights from field observations, interviews and documents related to the phenomenon under investigation, the researcher begins the iterative process of highlighting key themes, identifying commonalities and connecting relationships between emergent variables of importance – a process which represents the structural foundation of grounded theory (Strauss and Corbin, 1990). As the nature of influential variables and the relationships between the variables are refined, the scoping questions, which guided the first semi-structured interviews, are supplemented by additional questions that the researcher progressively develops in order to clarify emergent understanding (Charmaz, 2006). This fosters cognitive "deepening" that Comi and colleagues argue is vital for rich analysis of environmental networks (Comi et al., 2015). Table 1 outlines the initial scoping questions that were used to begin the interviews.

Once influential variables are categorized and variable interdependencies become clearer, the researcher continues to explore peripheral elements of the phenomenon being studied. The intent is to try to gain as full of an understanding as possible of the system under investigation. When the researcher gets to a point where further interviews, documents and observations fail to yield new insights, the research is said to have reached a stage of knowledge saturation (Strauss and Corbin, 1990). At this stage, the researchers are then ready to present the variables and interdependencies in a theoretical form which can subsequently be validated empirically. All of this was done for the research being described in this paper, with the major deviation being a decision to evaluate the interdependencies between the variables after all the interviews were done. This was deemed necessary due to the condensed schedule over which the interviews were conducted, which left very little time for the construction of cognitive models while in the field.

Interviews were conducted during the month of August 2014 in Kalundborg, Denmark and follow-up enquiries were conducted by e-mail or telephone. Interview subjects included senior executives

**Table 1**
Interview scoping questions.

1. Can you please describe your firm's role in the KS?
2. What caused your firm to seek out such collaboration?
3. What is your assessment of the collaboration?
4. What do you think has made the KS a success?
5. Do you continue to search for new collaborative opportunities? If so, in what areas and why? If not, why not?F

from many of the key enterprises that participate within the KS. Executives who were interviewed came from the following firms: Novo Nordisk (the world's largest producer of insulin), Novozymes (one of the world's largest producers of enzymes for various uses), Statoil (a large oil refinery in Kalundborg), DONG Energy (the largest coal-fired power plant in Denmark), Gyproc (a manufacturer of wallboard), Inbicon (a biofuel producer), Kalundborg's municipal waterworks (called Kalundborg Forsyning), Kalundborg City Hall and by telephone, RGS 90 (a company which treats polluted soil). In addition to this group of executives, the research benefited significantly from valuable input from staff and associates of the Kalundborg Symbiosis Center, an organization that was created in 1996 to provide outreach to individuals and researchers who are interested in documenting the KS. In the spirit of Lashley and Taylor (2010), interviews with many of the core participants were arranged in advance but a snowball approach that was applied during the interview process yielded new opportunities to interview additional stakeholders. The interviews lasted between 30 and 90 minutes with most extending over one hour. There were return visits to the Symbiosis Center and follow-up e-mail and telephone correspondence with many of the subjects who were interviewed for this project. Overall, 14 subjects were formally interviewed for this project and a number of other stakeholders encountered during the course of the site visits were consulted for views. The anonymity of the interview subjects has been preserved for privacy.

## 4. Kalundborg Symbiosis background

It has been said that the seeds of what has transpired in Kalundborg were sowed by a cooperative project in 1961 that involved the construction of a 13 km long pipeline to supply water from Lake Tissø to a new oil refinery, which at the time was called Dansk Veedol A/S (eventually to become Statoil). Enterprisingly, the municipality agreed to build the pipeline with a loan from Dansk Veedol (Christensen, 2014).

The first cooperative project between firms involved Saint-Gobain Gyproc and Dansk Veedol in 1972. This involved the construction of the pipeline to deliver gas that was being flared-off as an unwanted by-product of the oil refining process to Gyproc for drying gypsum boards (Christensen, 2014).

As time went on, other projects began to take shape and new firms entered the fray. The water pipeline was extended from Statoil to the Asnaes Power Station/DONG Energy so that the coal-fired power plant could re-use the cooling water from the refinery. The power station entered into an agreement with the municipality to supply district heating to the town and steam to Novo Nordisk and the oil refinery. Consequently, more piping was laid in the community to facilitate the transfer of steam. As Fig. 1 illustrates, by the end of the 1980s, there were at least 12 material exchanges between the firms in the KS (Christensen, 2014).

This emergent network of collaborations was not formally noticed until a meeting of an “Environment Club” in 1988, which was arranged in Kalundborg as a follow-on sustainability initiative stemming from the work of the Brundtland commission. The emergent network would not receive a formal identity until October 1989, when Kalundborg's sixth-form college organized a project week that focused on sustainability issues. Valdemar Christensen, who was one of the managers at the Asnaes coal-fired power station was at home preparing for his role in the discussions when his wife Inge pointed out the similarity between what was happening with the collaborating cluster of firms in Kalundborg and the symbiotic relationships that exist in the natural world between different organisms. Valdemar, appended the word “industrial” to distinguish this particular type of symbiotic network and in doing so, the couple sired the term “industrial symbiosis” – a term widely used to describe collaborations between firms where the transactions involve wastes from one firm being used by other firms as resource inputs (Christensen, 2014).

In 1990, a cardboard model that depicted the shared flows that were occurring within the Kalundborg municipality drew the attention of a local newspaper which published an article about what was happening. This article was picked up by the Financial Times, which subsequently reported on the phenomenon. By 1992, as world leaders were convening the Earth Summit, the Kalundborg Industrial Symbiosis had become a hot topic in environmental circles (Christensen, 2014).

By 1996, interest in what was happening in Kalundborg was extensive enough to encourage Kalundborg's local trade council to coordinate the planning of a “Kalundborg Symbiosis Center”, a project that was led by a committee consisting of representatives from the firms participating in the KS (Christensen, 2014). Now, 43 years since the first transaction, the Kalundborg Symbiosis has a central office funded by members of the KS and resource exchanges are occurring between almost 20 independent enterprises. As Fig. 2 demonstrates, the growth of these collaborative transactions has been remarkable given that these are all transactions between firms that are strategically unconnected and have occurred in an organic manner without central control.

## 5. Discussion of research findings

After coding and collating the interview notes, four collaborative drivers stood out as features that embedded the collaborations that have taken place in the KS. In this section, these drivers will be described in greater detail with an attempt to tie this in to existing theory.

### 5.1. Pragmatic environmental spirit

It should come as no surprise that key executives within the KS exhibit a high level of environmental awareness. However, this is not a radical green environmental spirit where the stakeholders involved seek to enact environmental change regardless of the cost. This is a softer environmental mindset, which comes across as more pragmatic, yet still environmentally connected. For example, while interviewing a senior executive at Novozymes, it became clear that the executive, who was a local resident, cares deeply about the connection between Kalundborg's industries and the development of the community. He sees it as being a natural part of doing business to think about connections to the community while undertaking business operations. Executives interviewed at Kalundborg Forsyning, Inbicon and Statoil expressed the same sentiments.

In other instances, the existence of high levels of environmental awareness can be attributed in part to corporate culture. Many of the firms within the KS are large organizations that have very sophisticated environmental management programs. For example, as a senior executive at Novo Nordisk points out, “our business culture is predicated on triple bottom-line thinking and so our strategic development always ensures attention is given to the

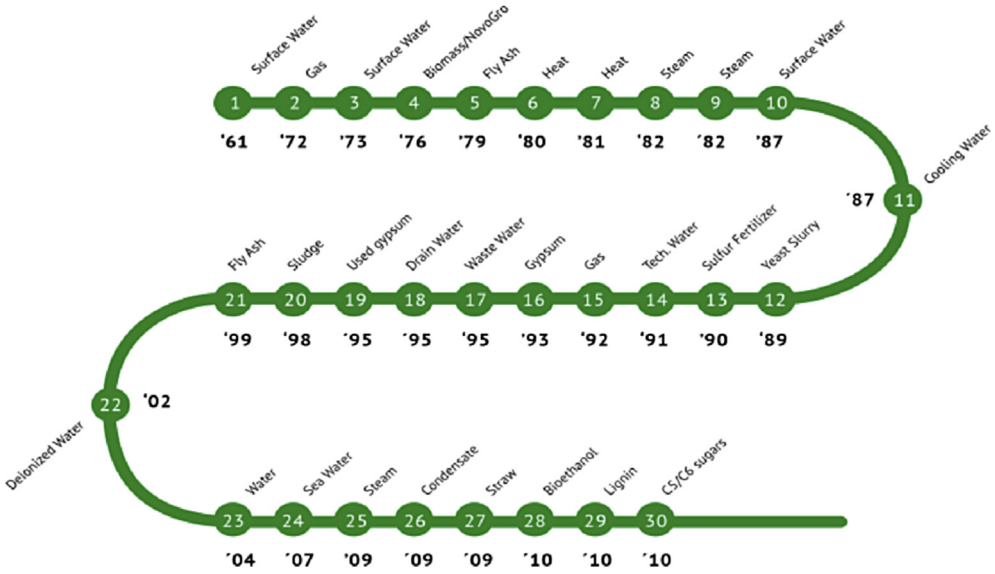


**Fig. 1.** Material transfers taking place in the Symbiosis, by year of commencement.
Source: Kalundborg Symbiosis office website: http://www.symbiosis.dk/en/evolution.

social and environmental impacts of our activities." Even for the firms that have highly sophisticated environmental governance systems, it is clear through interviews with non-local executives who commute into work (i.e. Novo Nordisk, Gyproc) that there is a high degree of pride associated with the types of activities undertaken in the KS.

### 5.2. Opportunities to explore possibilities

As highlighted earlier, the inter-firm collaborations that would come to be known as the KS sprung initially from social interactions that took place amongst Rotary Club members. Leading executives at DONG Energy (which was called Asnaes Power Station at the time), Dansk Veedol (now Statoil), Novo Nordisk and Gyproc shared a willingness to discuss key challenges that their organizations faced with members of their social circle. Through these conversations, Statoil and Novo Nordisk began to purchase steam from DONG Energy and the head of Gyproc starting purchasing gas from Statoil.

Interview subjects, when attempting to explain the development of the KS, highlighted that in the early days of the KS, most of the senior executives of the collaborating firms lived in the Kalundborg area. Therefore, there was a desire to embrace initiatives that benefited their firms while also benefiting the community. Indeed, interviews conducted by Marian Chertow of Yale University in 1998 with the founding generation of managers indicated concern about the continued viability of the KS because the incoming generation of managers had no ties to the community (Chertow, 2014).

When asked to comment on this concern, many of the interviewed executives acknowledged that times have changed and that many key decision makers now commute long distances to their jobs in Kalundborg. Although they acknowledged that non-residence inhibits socializing with executives from other firms in the same manner that their predecessors did in the 1970s, many counter that the KS has evolved and adopted more formal structures to provide opportunities for interaction. The Kalundborg Symbiosis Center plays a key role in this process because it frequently hosts events and coordinates meetings that connect executives from firms within the KS.

### 5.3. Mutually beneficial initiatives

Most of the executives interviewed made a point to emphasize that the success of the KS is predicated on collaborations that make business sense – initiatives that benefit all of the economic entities involved. In the words of Wang et al. (2013), symbiosis profit appears to be the superordinate criteria for incentivizing collaborations in the KS. Reciprocity has been empirically linked to collaborative success (Fiedler and Deegan, 2007); and in Kalundborg, this is on full display. Table 2 summarizes some of the more prominent collaborative activities within the KS and highlights the benefits to each party. A senior executive at Novozymes sums up the overarching desire for commercial benefit, "*this is not an NGO trying to save then world; this is business.*"

As Table 2 suggests, all of the activities that comprise the KS are commercial transactions, benefiting both parties economically. As Søren Carlsen, Senior Director of Novozymes A/S emphasizes, "*there's no doubt that Novozymes with its involvement in the Kalundborg Symbiosis has found solutions that help us to keep expenses at a minimum for water, steam and liquid waste treatment*" (Carlsen, 2014). This then represents the "collective action" frame of the participants (Lashley and Taylor, 2010) – collaboration represents good business. In some cases, money actually changes hands, as one firm pays for the byproducts or outputs of another firm. In other cases, resources are shared without financial payment because the act of giving away the resources mitigates what would otherwise be a disposal cost. In yet other cases, firms collaborate to build infrastructure that can be commonly used (i.e. gas, steam and water pipelines).

Those interviewed were quick to point out the importance of mutual benefit in sustaining this environmental network. In the words of Hans-Martin Møller, CEO of Kalundborg Forsyning, "*It has been of great importance to Kalundborg Forsyning (the local water and heat supplier) that agreements in the Kalundborg Symbiosis should be based on the same technical and economic foundations and that the collaboration with the partner industries should not burden the other customers with extra expenses or cause technical difficulties*" (Møller, 2014). As Jan Hoff, Senior Vice President of Novo Nordisk A/S adds, "*like with good neighbors, the partnership in the Kalundborg Symbiosis is based on participants who actively invest time and resources in*

## Kalundborg Symbiosis

*Diagram 1961-2010*

| | | |
|---|---|---|
| 1 | Surface Water | *1961* |
| 2 | Gas | *1972* |
| 3 | Surface Water | *1973* |
| 4 | Biomass/NovoGro | *1976* |
| 5 | Fly Ash | 1979 |
| 6 | Heat | *1980/89* |
| 7 | Heat | *1981* |
| 8 | Steam | *1982* |
| 9 | Steam | *1982* |
| 10 | Surface Water | *1987* |
| 11 | Cooling Water | *1987* |
| 12 | Yeast Slurry | 1989 |
| 13 | Sulfur Fertilizer | 1990/2001 |
| 14 | Tech. Water | 1991 |
| 15 | Gas | 1992 |
| 16 | Gypsum | 1993 |
| 17 | Waste Water | 1995 |
| 18 | Drain Water | 1995 |
| 19 | Sludge | 1998 |
| 20 | Fly Ash | 1999 |
| 21 | Deionized Water | 2002 |
| 22 | Water | 2004 |
| 23 | Waste | 2004 |
| 24 | Sea Water | 2007 |
| 25 | Steam | 2009 |
| 26 | Condensate | 2009 |
| 27 | Straw | 2009 |
| 28 | Bioethanol | 2010 |
| 29 | Lignin | 2010 |
| 30 | C5/C6 sugars | 2010 |

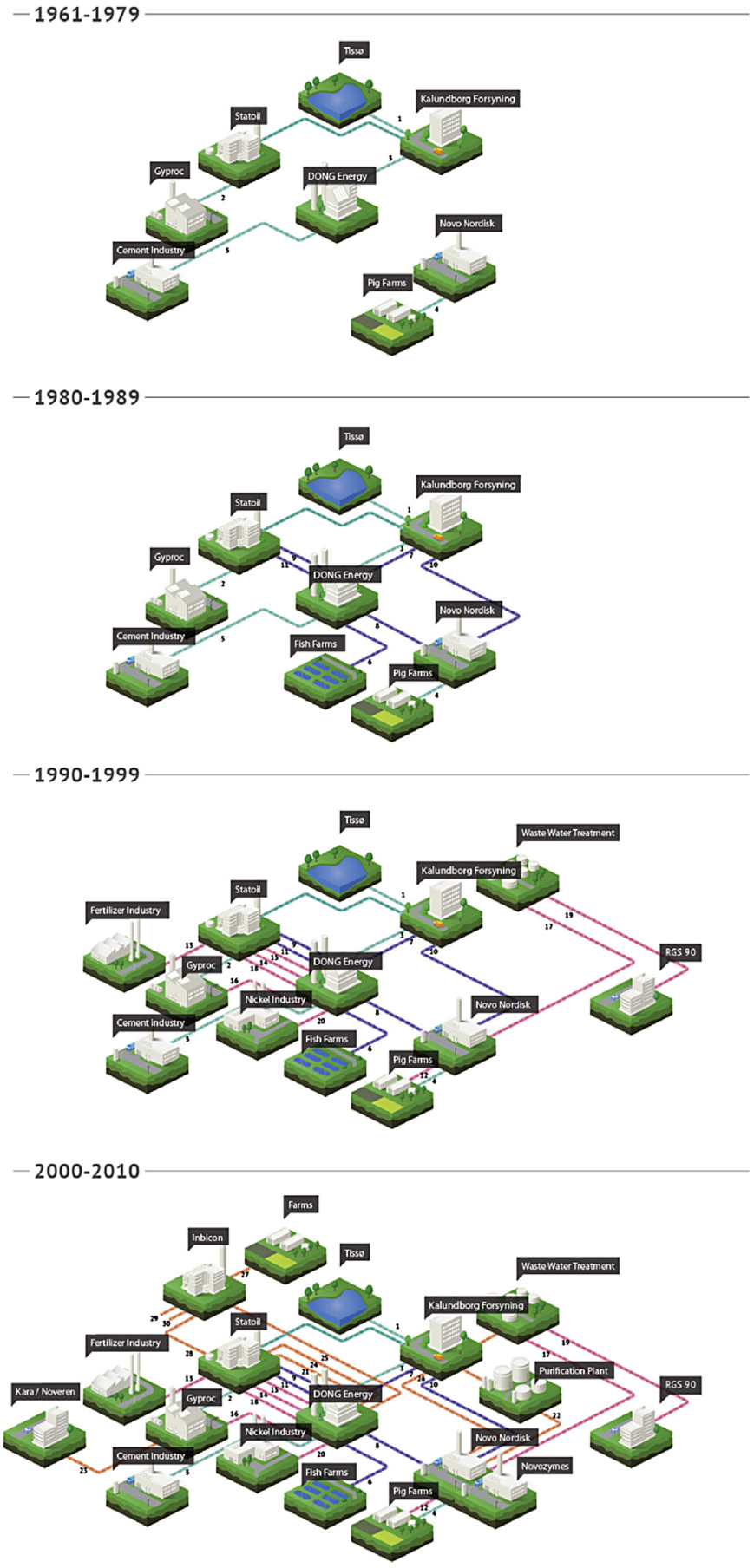


**Fig. 2.** The evolution of the Kalundborg Symbiosis. http://www.symbiosis.dk/sites/default/files/Symbiose_A4_cmyk_uk.pdf.

**Table 2**
Mutual benefits of the Kalundborg Symbiosis activities.

| Year | Collaborative activity | Party A | Party B | Benefit to Party A. | Benefit to Party B. |
|---|---|---|---|---|---|
| 1972 | Natural gas transfer | Dansk Veedol/Statoil | Gyproc | Sale of production byproduct | Local acquisition of key resource |
| 1973 | Acquisition of surface water | Municipality of Kalundborg | DONG Energy | New jobs, sharing of pipeline costs | Acquisition of water, sharing of pipeline costs |
| 1976 | Yeast slurry transfer | Novozymes | Local farms | Mitigate disposal costs | Cheaper source of fertilizer |
| 1979 | Fly ash transfer | DONG Energy | Cement industry | Mitigate disposal costs | Cheaper source of key factor input |
| 1980 | Heat transfer | DONG Energy | Fish farms | Payment for a waste stream | Operational enhancement |
| 1982 | Steam transfer | DONG Energy | Statoil | Payment for a waste stream | Cheaper steam |
| 1982 | Steam transfer | DONG Energy | Novo Nordisk | Payment for a waste stream | Cheaper steam |
| 1993 | Transfer of fly ash byproduct | DONG Energy | Gyproc | Mitigate disposal costs | Cheaper source of Gyproc |
| 2004 | Purification of water | Municipality of Kalundborg | Novozymes/Novo Nordisk | New revenue stream, improved wastewater treatment | Cheaper source of key factor input |
| 2009 | Straw transfer | Local farms | Inbicon | New revenue stream | Critical resource for pyrolysis |

*the relationship. We invest because through … open dialogue we believe that we get something in return*" (Hoff, 2014).

### 5.4. Dominant needs stimulating proactive search

Although interview subjects did not directly acknowledge this, it became clear during site visits to many of the factories and businesses that collaboration centered predominantly on the dominant needs of the major network players. This is in alignment with research that indicates that firm size and willingness to collaborate share a positive relationship (Dangelico and Pontrandolfo, 2013) and that dominant resource acquisition or disposal requirements provide incentives to proactively search for solutions (Lambert and Boons, 2002). For example, DONG Energy was producing a surplus of steam and generated a large amount of fly ash as a result of combusting coal. Although handling the steam was not a problem, it represented a wasted resource and so executives of DONG were receptive to alternative uses. On the other hand, disposal of the fly ash was an ongoing expense and an administrative burden. Therefore, executives of DONG were keenly interested in seeking out ways to reduce this waste disposal cost. Consequently, it is not surprising that DONG's participation in the KS centers on managing these two challenges.

Similarly, across the road from DONG, Statoil executives were challenged by two resource issues. First, they were keenly aware of the cost and administrative burdens associated with generating steam; however, it had to be managed because steam is a vital component of the refining process. Clearly, Statoil executives would have been keen to try and manage this process in a more cost-effective manner. Secondly, a key byproduct of the refining process is the production of natural gas which, in early days, was flared off, rendering it to be a wasted resource. Accordingly, when it came up in conversation that Gyproc, down the road, was using gas to dry its wallboards, a symbiotic solution was born.

Indeed, in Kalundborg, all of the prominent waste flows that are exchanged within the KS represent major waste management or resource procurement challenges for the participating firms. This notion of designing collaborative symbiosis around dominant needs is as true in the present day as it was in the past. Executives who were interviewed readily acknowledge that the KS really is about better business and the first step toward better business in a resource context is to pick the "low hanging cherries" by implementing solutions that save the most at the least cost (Valentine, 2012).

### 5.5. Progression of collaborative relationships

#### 5.5.1. From cautious engagement

It became evident during the interviews that there was a clear progression of relationships that was contingent upon the progressive development of trust. All interviewees were keen to laud the trust that exists between members of the KS. However, two of the executives interviewed were also careful to point out that this did not come naturally; nor was trust the only tie that binds the KS together. All of the major transactions within the KS are governed by contract and subject to legal reparations should either side of the agreement failed to deliver.

Indeed, as a senior executive at Statoil explained, "*the decision to purchase steam from DONG Energy in 1982 was not a decision that was taken lightly*". In the absence of steam, the refinement of oil simply cannot be undertaken. Therefore, in the early days of the contract with DONG Energy to provide steam for Statoil, Statoil kept its own steam plant in operational order, as a backup. Should anything happen with the supply of steam from DONG Energy, Statoil was not exposed to operational risk. It wasn't until the relationship with DONG Energy began to mature that cautious engagement turned to trust and Statoil decided to decommission its steam plant.

Similarly, over at the Gyproc plant, to this day the managing director of the plant maintains two supplies of gypsum – one supply of natural gypsum that is imported and one supply of gypsum that comes from the waste flows of the DONG Energy plant. Although the commercial arrangement concerning delivery of gypsum is covered by contract and the relationship between the two organizations is strong, Gyproc still maintains strategic supply diversity.

#### 5.5.2. Growing confidence in resolving problems

However, when executives were asked to identify what has *sustained* the KS for over 40 years, all interview subjects conjured up the same word – trust. Trust which was amassed over time. This link between trust based on experience and willingness to collaborate is empirically supported (Paulraj et al., 2014). For many participating firms, the cautious engagement period gave way to trust as transactions between the partners were consistently completed on time and to specification. As confidence rose due to successful collaborative performance, some members of the KS seem to have naturally come to consider the network as a strategic

conduit that might be useful for adding value and supporting future strategic plans.

DONG Energy exemplifies why many experts refer to trust as a feature of "social capital", suggesting that this is a shared asset (Pike et al., 2005). DONG provides steam to Statoil and Novo Nordisk. In both cases, consistent, reliable delivery of steam is mission critical to these purchasing firms. Over time, the reliability of service provided by DONG Energy has fostered positive relationships that have, in turn, instilled a degree of confidence in the partnership. Consequently, as discussions ensue about the prospects of closing the DONG Energy plant, there is no sense that executives at Statoil or Novo Nordisk view the possible loss of steam as an imminent threat. Although this lack of alarm is likely in part due to the fact that these are major firms which can easily solve the curtailment of steam through in-house solutions, it is also partly because the executives at DONG Energy communicate their plans to their partners and have demonstrated their willingness to support the relationship. One way they convey this is by initiating other trial projects (Inbicon, Pyroneer) to generate steam, should there be a decision made to close down the coal-fired power plant.

The greatest current threat to the viability of the KS stems ironically from the Danish national climate change strategy, which aims to phase out electricity generated by coal-fired power plants. As a result of this, the Kalundborg coal-fired power plant has been generating diminishing amounts of electricity and now predominantly operates to generate steam for other entities within the KS. There is a strong possibility that using coal to generate steam will also be discontinued in years to come, suggesting that DONG Energy's core role within the KS might disappear.

In response, DONG Energy has invested in two pilot projects – a bioethanol manufacturing plant that uses straw from local farms (Inbicon) and a regasification plant (Pyroneer). Together, these plants might give DONG the capacity to produce sufficient steam to sustain the needs of firms within the KS even if coal-fired steam is phased out. As one of the directors of DONG Energy points out, "*thanks to the cooperation that existed as a result of the Kalundborg Symbiosis, the decision to site the two pilot plants in Kalundborg was an easy decision*" (Kjaer, 2014).

In terms of what a shut-down of DONG's coal-fired power plant means from the perspective for other firms in the KS, Gyproc has successfully diversified its gypsum inventory; and so losing gypsum from DONG Energy would not be strategically damaging – just unfortunate because there is economic value entwined in this resource. Statoil has yet to devise a strategy to replace the steam which might be lost from the closure of the coal-fired power plant because it has the technical expertise to solve the problem in-house in a very short period of time, if necessary. Novo Nordisk is in the same boat in regard to the supply of steam; it can replace the resource if need be.

The environmental vision that many executives share suggests that replacing steam generated by coal with steam generated by a cleaner source might be an acceptable solution. As a senior executive at Novozymes explains, "*if DONG can shift production of steam to 100% renewable sources then most of the partners will be willing to pay the premium.*"

There is no sense of alarm when potentially affected firms speak about an impending closure of the coal-fired power plant. There is a sense that all the members of this supply chain have enough "relational capital" (Pike et al., 2005) to ensure that the firms will continue to collaborate as long as possible; and when this is not possible, they will simply solve any emergent problems on their own accord. This isn't blind faith but rather confidence and a "shared norm" that a solution can be found, preferably within the network (Ashton and Bain, 2012). As Jan Hoff of Novo Nordisk points out, "*we spend more time finding solutions than discussing how to share the benefit*" (Hoff, 2014).

Amidst this backdrop, other network members such as Kalundborg Forsyning – the local wastewater treatment plant – view the potential closure of DONG's coal-fired plant as an opportunity to play a role in effecting a possible solution. Kalundborg Forsyning is currently operating a test and demonstration facility – E4Water – for treating wastewater with micro algae, which will then be used for the production of biofuel in order to provide fuel for steam generation should the coal-fired power plant be shuttered (Damm, 2014). This then provides clear evidence of an "adaptive response to environmental uncertainty" (Fiedler and Deegan, 2007). As problems emerge, there seems to be an entrepreneurial willingness on the part of firms that could conceivably play a collaborative role in problem solving to step up and seize the opportunity. Moreover, thanks to ongoing communication and collaboration, these opportunities are uncovered early enough for firms to begin to trial potential solutions.

#### 5.5.3. Strategic awareness of collaborative benefits

Beyond confidence in solving immediate problems, some members of the KS exhibit a high degree of comfort with the notion of strategic collaboration within the network. Perhaps one rationale for this stems from proactive engagement with the KS on the part of the Municipality of Kalundborg. Key civil servants in the municipal office frequently engage with officers at the Kalundborg Symbiosis Center to discuss developmental strategy. Moreover, some civil servants who run the utilities – such as Kalundborg Forsyning – view public sector challenges within the community in the same holistic manner that the KS is now conceptualized in and so they become potential central cogs in the process. As Hans-Martin Møller, CEO of Kalundborg Forsyning pointed out, although wastewater treatment is typically considered to be a mundane operation undertaken in a centralized manner, the possibilities of utilizing the waste flows from wastewater treatment to support other needs within the KS are significant if viewed through a lens of strategic foresight. He contends, "*we could position ourselves as central to this process, helping the network involve to Industrial Symbiosis 2.0*".

The story of the birth of one of Novozymes divisions – Novogro – highlights how collaborative success can engender innovation that goes beyond simple problem solving. In 1976, Novozymes, which creates enzymes for various different processes, encountered an operational challenge. The yeast slurry from its production processes was being disposed of at a significant cost. However, executives in Novozymes noted that this waste stream was nutrient rich and could conceivably substitute for fertilizer in agricultural settings. Novozymes made contact with farmers in the region and after presenting them with a certificate of analysis for the nutrients contained in the slurry, Novozymes offered to give them the slurry for use on their crops. Over time, the slurry that Novozymes needed to dispose of grew in volume and gradually came to exceed the utilization rate at local farms. Therefore, engineers sat down to think about what they could do with the excess yeast slurry. Since it was already proven that the yeast slurry was of value for farmers, a decision was taken to de-water the slurry in order to create solid pellets which could be packaged and distributed beyond the Kalundborg region. This series of events culminated in the development of a new division for Novozymes. As an executive at Novozymes emphasized, "*without the activities underpinning the symbiosis, it is doubtful that engineers in Novozymes would have been as externally focused as was needed to create this new business.*"

In summary, there appear to have been four antecedent conditions driving the KS collaborations – a pragmatic environmental mindset, opportunities to explore possibilities, the existence of

mutual benefits underpinning the collaborations and dominant resource acquisition or disposal needs that encouraged a proactive search for solutions. Once the collaborations commenced, there was a progressive process that saw the relationships deepen, establishing fertile grounds for further collaborations. Collaborations began tentatively through cautious engagement. Trust which grew from these initial collaborative forays matured into confidence in solving problems – collaborations became a part of the operational fixtures in many of these firms. For some of the firms, these collaborative relationships are now beginning to deepen further, as the next section will document.

### 5.6. Evidence of progression toward sustained collaboration

As Marian Chertow notes, over the 40 year existence of the Kalundborg Symbiosis, there have been at least three significant changes that could have derailed collaboration. The size of the oil refinery doubled, which significantly altered resource needs and resource flows. Two changes to the fuel mix of the power plant altered resource needs of the plant and ensuing waste flows. A natural transition in organizational leadership has resulted in the replacement of all the executives that were instrumental in the pioneering days of the KS (Chertow, 2014). In an environmental network that lacked resilience, any of these changes might have caused the collaborative initiatives to fizzle out. Yet 40 years later, the KS is still going strong. Results of this research indicate that the reason for this stems from enhanced firm embeddedness that can be described by a three-stage process. Fig. 3 graphically illustrates the evolution of many of the relationships within the Kalundborg Symbiosis.

During the first stage – cautious engagement – participating firms entered the network through some form of interactive opportunity afforded to the executives. This might have been through a social group (such as the Rotary Club) or a more formal interactive mechanism (such as through the auspices of the Symbiosis Center which plays a consolidation role for the members). However, interaction alone was not sufficient to spur on collaboration. For parties to engage with each other, there needed to be a resource flow that another member could utilize in an advantageous way. Some relationships never really evolved from this stage. For example, the transfer of excess gas from Statoil to Gyproc ended years ago and so Gyproc's role in the KS is now limited to receiving gypsum from the coal-fired power plant – a transaction that it hedges against by maintaining its own supply of natural gypsum. Gypsum still values the relationship with the KS but it does not see other opportunities for collaborations of any significance.

At the second stage – cooperative escalation – some firms who began to cooperate on a given project eventually achieved a high degree of operational comfort whereby the transaction that catalyzed the cooperative initiative becomes a normal part of business processes. At this stage, operational challenges associated with sharing resource or waste flows have been sorted out and the cooperative project becomes institutionalized in a manner that is not dissimilar to a supply chain relationship. Comi and colleagues refers to this as “transactional collaboration” (Comi et al., 2014). What once was a transaction between two strategically disconnected entities now evolves to form part of the norm for both firms. This stage of entrenched trust establishes the conditions necessary for executives from the cooperating firms to share concerns over existing business challenges and explore opportunities for further cooperation. In Kalundborg, the relationships between Statoil, DONG Energy, Kalundborg Forsyning, Novo Nordisk and Novozymes fit this mold.

For firms that are successful in identifying further collaborative opportunities, this then leads to the third stage – operational

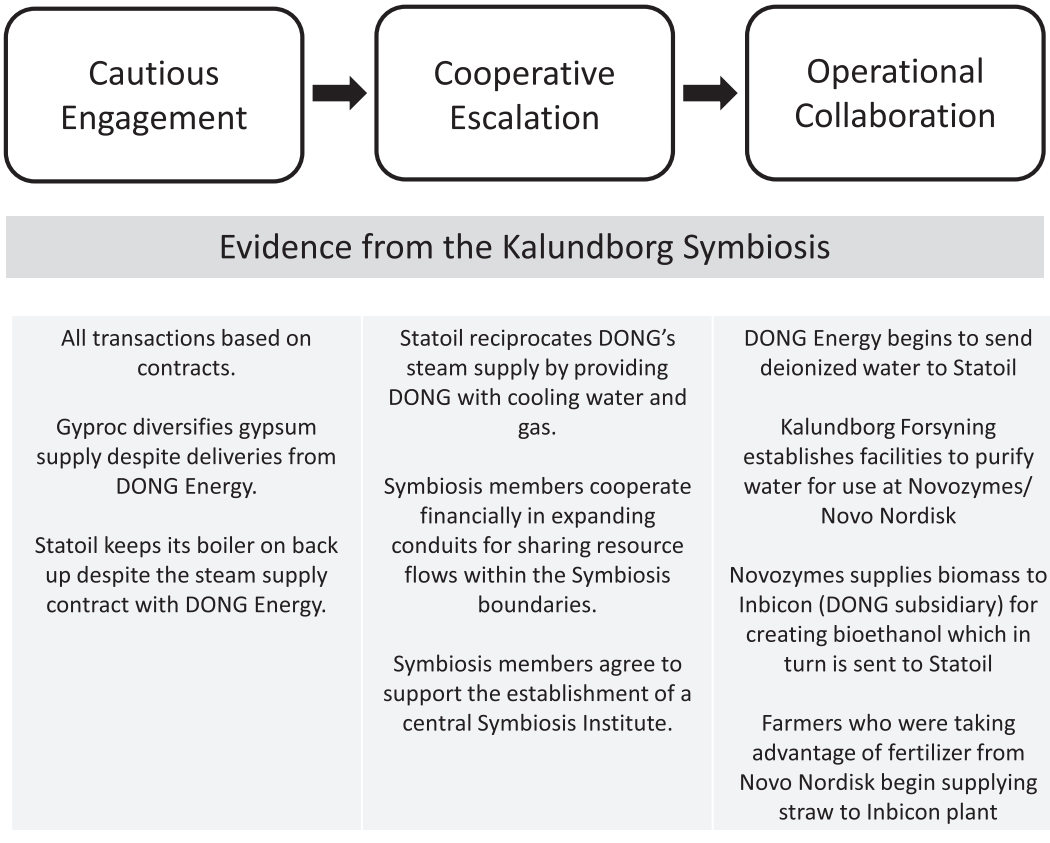


**Fig. 3.** Evolution to sustainable collaboration in Kalundborg.

collaboration – which at its core represents a conceptual shift in the relationship from cooperating (two separate entities reactively working together) to collaborating (two separate entities proactively working together). Comi and colleagues refer to this stage as "consultative collaboration" (Comi et al., 2014). The level of trust that has accrued by this stage provides the foundation for executives from the collaborating firms to willingly share emergent problems almost as if the two previously strategically disenfranchised firms were now part of a unified strategic alliance. At this stage, the collaborating partners do not necessarily expect collaborative problem resolution at every juncture and for every emergent problem; however, thanks to a proven track record of operational success in the collaboration, business challenges that at one time might be confidential are now introduced to the relationship. This is an important development in a collaborative relationship. As Pike and colleagues argue, "*building an effective network requires a commitment from participants to share more than they normally would*" (Pike et al., 2005).

Within the Kalundborg Symbiosis, even the most active participating firms have not yet arrived fully at this third stage and most have not even reached this juncture. On the one hand, in the interviews, executives of Statoil, DONG Energy, Inbicon, Kalundborg Forsyning, Novo Nordisk and Novozymes all demonstrated strategic awareness of the business challenges facing the executives of each of the other firms in this core. They also voiced a commitment to working with each other to try and resolve major issues that threatened the collaboration. As Søren Carlsen of Novozymes explained, "*Based on previous cooperation and the mutual obligation that the Kalundborg Symbiosis embodies, we foresee that solutions will also be found in the future that can ensure our possibility of having a production that is both attractive from the point of view of the environment and in operating the economy. The cooperation that has been going on for many years now between industry and the municipality makes it natural that major projects involving energy consumption and waste management are organized as a joint effort*" (Carlsen, 2014).

On the other hand, strategic ties are still very loose and tend to revolve around resource procurement. The core group that has demonstrated an interest in advancing collaboration seems to have hit an innovation wall. As one senior executive at Novozymes explained, "*twenty years ago there was a high degree of interest in exploring new possibilities and the stakeholders in the Symbiosis would meet about four times per year. However, the frequency of meetings has declined*". The Kalundborg Symbiosis Board of Directors now only meets two times per year. The last meeting to explore new areas for collaboration occurred two years ago and yielded no results.

Research suggests that a central reason why this stage is hard to fully realize in an environmental network is because the collaborating organizations begin to encounter a dilemma between individual and collective benefits (Prager, 2015). In short, the principle of mutual benefit that drove the evolution of the KS is becoming harder to realize as the low hanging cherries that spurred on collaboration in the past are plucked from the tree (Lambert and Boons, 2002). Going forward, the network core could clearly benefit from the identification of strategic collaborative opportunities that could deliver mutual benefit. The question is, how can this be fostered? The next section considers the possibility of a municipal response to this conundrum.

## 6. The role of policy in supporting sustainable environmental network collaboration

### 6.1. Background

In Kalundborg, the role of the municipality has evolved as the network has expanded. From the outset, it was an active participant because the scarcity of ground water in the Kalundborg area necessitated effective use of the water that Lake Tissø could provide. However, in addition to governing the water supply, Kalundborg municipal authorities also played a role as a proactive agent of change. As a Novozymes executive noted, "*the municipality and the board have been important catalysts. The local authorities in particular have been key in sustaining momentum within the symbiosis*." For example, the municipality procured heat for the community through a contract with the power plant in 1981, agreed to treat wastewater and sludge from Novo Nordisk/Novozymes under a special contract in 1995 and contracted with the same firms to purify water for their processes in 2004.

As the municipality celebrates the 40th year anniversary of the KS, the municipality's industrial and development policy reflects an ongoing desire to continue to be an agent of change. Its vision for 2011–2014 was expressed in the following manner:

> "*We want to create sustainable growth through increased focus on innovation, new technology and better resource efficiency through symbiotic thinking. The Kalundborg municipality is playing an active role in the transition to a climate-friendly and energy-efficient community, independent of fossil energy sources with the constant focus on exploiting and testing possibilities in new green technologies*" (Damm, 2014).

There is a different mindset that is evident with the strategic thinking of Kalundborg's municipal leaders. As Henrik Damm, the CEO of the municipality states, "*on the one hand, the city administration (serves) a regulatory role in relation to local industry so that concerns for the environment and the interests of the citizens are taken into account; but on the other hand, it also has to enter into constructive dialogue on how resources can be used in the best possible way*" (Damm, 2014).

As part of a drive to enter into constructive dialog on resource usage, the municipality has recently launched two new projects to explore how the symbiosis mindset can be extended to other areas of municipal oversight. One project investigates how closed-loop thinking can revitalize urban development by exploiting connections between "urban and rural areas, infrastructure, family life and many other things". The second project explores broadly the concept of sustainable development and how closed-loop thinking can be applied to facilitate improvements in health, education, biodiversity, leisure activities and the economy (Damm, 2014). The municipality is very much involved in work being done by the Kalundborg Symbiosis Center; however, not in a domineering manner. The municipal authorities were merely seen as stakeholders that could add-value to the process.

### 6.2. A critical juncture

It was also clear from the field investigation that the KS is at a crossroads with the potential closure of the coal-fired power plant. As a senior manager of Statoil mentioned in an interview, "*given the financial challenges facing oil refineries in this day and age, we fear that the loss of the steam supply might wind up being the straw that breaks the camel's back and sways the decision to close down or relocate the refinery.*" As the list of material flows in Fig. 2 suggests, if both the power plant and the oil refinery were to close down, many of the collaborative exchanges would disappear.

This suggests that the Kalundborg municipal managers should also be viewing this period as a juncture where a major strategic decision might be needed. It might have to decide to either i) allow the KS to survive or parish based on natural economic forces or ii) strategically intervene to encourage a new round of evolution. Given the importance with which the municipality views the

existing network and the role that closed-loop thinking can play in plotting out the future of Kalundborg, the municipality might wish to proactively expand its influence within the KS. As US Senator Mike Crapo points out in a similar context, "*policy development through collaboration at the local level is more efficient, avoids litigation, increases access to decision-making, and leads to more stability*" (Crapo, 2004). These are all desirable outcomes for a municipality that wishes to leverage closed-loop thinking to enhance community development.

As mentioned earlier, evidence indicates that the evolution of systems thinking within the KS is underpinned by mutual financial benefit. This has inspired firms to share gas, water, steam and major waste flows. However, when it comes to encouraging innovation in areas where the cost savings are not obvious, collaboration appears to vanish. In discussing this phenomenon with one of the senior executives at Novo Nordisk, the executive admitted that it was hard to find the time to allocate engineers to a project designed to flesh out collaborative options, without a clear idea of what results might be produced. A senior engineer at Statoil concurs. He pointed out that a number of engineers from the core firms have already met once to explore further collaborative possibilities and the process yielded no further initiatives. So what is the Kalundborg municipality to do if it wishes to infuse new collaborative vitality into the network?

### 6.3. A cognitive model for understanding corporate needs

To address this challenge it might be worth directing attention to work by Valentine into the nexus between corporate environmental governance and public policy (Valentine, 2012). Valentine's work focuses on firm-level environmental governance initiatives but the principles put forth in this work also apply to collaborations. He argues that firms that embark on a journey toward enhanced environmental governance begin with initiatives that he calls "low hanging cherries". These initiatives typically focus on easily implemented actions that promote significant and often immediate cost savings.

When applied to what is transpiring in Kalundborg, one sees a significant amount of evidence which supports the existence of this phenomenon. The major flows between the core firms – DONG Energy, Statoil, Novo Nordisk/Novozymes, Gyproc – consist of major resource inputs or wastes that engender significant savings when exchanged. In all cases, investments were required but the projects were implemented over a short period and the benefits were almost immediate.

Valentine argues that as a firm adopts enhanced environmental governance initiatives, there comes a stage where further progress must be driven by "cost saving investments". Designing these types of initiatives requires specialized knowledge (Simpson, 2012); and although they can produce positive returns, the results materialize over a longer time frame (Valentine, 2012). When this insight is applied back to the Kalundborg case, it is apparent that few collaborative initiatives mirror these longer term "cost saving investments". The few initiatives of this type that do exist are characterized by municipal involvement. For example, the 2004 collaboration between the Municipality of Kalundborg and Novozymes/Novo Nordisk to provide a supply of purified water represents a cost saving investment. Therefore, public authorities might be able to infuse new vitality into the network by seeking ways to support these types of initiatives that require investment.

### 6.4. Knowledge, time and incentives

In discussing how local government can support strategic collaborative investment of this type, Valentine argues that firms: i) must have access to enhanced environmental management knowledge, ii) must be willing to provide sufficient time to technical staff to think about problems and design innovative solutions and, iii) must be provided with proper incentives to invest (Valentine, 2012).

Enhancing environmental management knowledge can be directly provided by local municipalities. For example, in Singapore, the Singapore Environment Institute (which is part of the National Environment Agency) commissions experts to run environmental innovation workshops that are directed at members of the corporate community.[1] They also run a program entitled the Programme for Environmental Experiential Learning (PEEL) which centers on shuttling interested parties to local firms that are employing environmental innovations in order to see how these innovations are applied in the field. Alternatively, an indirect way of providing firms with enhanced environmental management knowledge is to offer tax credits or subsidies to firms for employing outside consultants or experts to advise on technical approaches for enhancing environmental governance. As another example from Singapore, the Singapore government has previously offered a 50% tax credit to firms for employing energy consultants (Valentine, 2012). In the case of Kalundborg, the Symbiosis Center is currently well-staffed with individuals who are increasingly connected to other environmental initiatives that are going on throughout Denmark and beyond. They have the capacity to take on a "net broker" role that encourages free thinking and pushes the participants to higher levels of performance (Perz et al., 2010). With an elevated operational budget, the center could easily provide some of the programs for enhancing environmental management knowledge within the KS. As Dangelico and Pontrandolfo (2013) point out, infusing an environmental network with new perspectives from universities and research institutions can significantly elevate green innovation.

The challenge of providing sufficient time for technical staff to think about problems and design innovative solutions is not without complications in competitive industries. It appears from the interviews that one of the reasons that more innovations are not occurring at a greater pace within the KS is not from lack of interest, but from rather from lack of time. As one of the executives of Novo Nordisk observed, "*if we had more time and flexibility to simply assign engineers to an innovative process, it is likely that we would want that person to focus on internal challenges that are of major concern, not some of the smaller challenges that could be uncovered by further collaboration within the symbiosis.*" With that said, given the proven willingness of firms within the KS to proactively collaborate, it is likely that if the municipality provided training and workshops (that were not overly time-consuming) to unlock collaborative innovation, corporate participants within the KS would take part. One of the two caveats associated with this recommendation is that, if the municipality were to adopt such a strategy, the efficacy of the first event would be mission-critical. Failure to uncover profitable opportunities for collaboration during the first event would likely discourage participation in follow events. The second caveat associated with this recommendation is that this Danish network is supported by a unique sociocultural environment. Simply put, a collaborative spirit is common in Denmark (Halloran et al., 2014) and a high degree of value congruence is evident (Pike et al., 2005). Therefore, one might be justified to question the external validity of applying a voluntary collaboration strategy in other nations.

[1] More on the programmes on offer at the Singapore Environment Institute is available at: http://sei.nea.gov.sg/index.html.

This then leads into the third element that Valentine contends is essential to encouraging strategic collaborative investment – incentivization (Valentine, 2012). Although some researchers contend that recycling, resource conservation or waste disposal legislation could conceivably incentivize corporate entities to improve environmental governance (Jiao and Boons, 2014), the collaborative spirit within the KS and the desire of municipal leaders to enact decisions that are both economically and environmentally beneficial suggest that "carrots" might be more effective than "sticks" when applied in Kalundborg (Bemelmans-Videc et al., 2003). Softer policy instruments such as green investment tax credits, innovation grants or collaborative subsidies can be used to incentivize behavior that, otherwise, might not be forthcoming.

These softer policy instruments can be structured in a way to target specific environmental outcomes (i.e. reducing $CO_2$ emissions), encourage innovation (i.e. collaborative R&D grants), incentivize common use of resources (i.e. investment tax credits for approved collaborative investment) or simply construct material flow models that Lambert and Boons (2002) argue are instrumental first steps in encouraging strategic evolution of eco-industrial initiatives.

Given the positive relations between authorities from the Municipality of Kalundborg and the Kalundborg Symbiosis Center, it is entirely feasible that the municipality can assume the role of what Frame and colleagues refers to as a "collaborative planner" (Frame et al., 2004) and assume a far more proactive role in spurring on further collaboration by intensifying the partnership with the Symbiosis Center. For example, a recycler of waste oil – Avila Oil – has recently relocated to Kalundborg but it has yet to formalize a role within the KS. If a comprehensive material flow model existed for the KS network, it might be feasible for the Kalundborg authorities to strategically target firms for inclusion into the network, as and Gibbs and Deutz (2007) suggest. This would elevate the level of planning sophistication within the KS to a level that Roberts (2004) refers to as a network eco-industrial park system.

Financial incentives could also be employed to encourage the corporate entities within the KS that already have experience in environmental collaborations, to begin to participate in what has been called "transformational collaborations" (Comi et al., 2014) – by turning their sights on supporting the broader initiatives that the municipality has embarked on to encourage closed-loop thinking to facilitate improvements in health, education, biodiversity, leisure activities and urban and rural community planning.

## 7. Conclusion and limitations to the study

The KS is one of the earliest documented examples of applied industrial ecology. Many of the main collaborations that developed within the network came to serve as archetypes for similar initiatives around the world. Consequently, it should come as no surprise that the KS, as one of the first industrial ecology networks, has achieved a state of maturity that represents a vanguard of a different type – the challenge of extending the scope of collaborations.

Reviewing the development of the KS yielded four antecedents which were instrumental in driving collaborations between the firms: i) a universally-evident pragmatic environmental mindset which encouraged the pursuit of environmental initiatives that also benefitted the firms; ii) opportunities to explore possibilities that were initially predicated on social connections and later entrenched through a formal symbiosis office; iii) mutually beneficial initiatives which ensured that the parties in a given collaboration were incentivized to make the relationships work; and iv) the presence of dominant needs that demanded the attention of senior management within the collaborating firms. As firms pursued these emergent collaborative benefits, relationships transitioned from cautious engagement to confidence in mutual problem solving. Yet limits to collaboration became apparent throughout the network.

Despite good intentions of the parties involved, the prospect of expanding the scope of collaboration encountered difficulties as collaborating partners found it hard to justify the time and lacked the motivation to search for new opportunities of mutual benefit. The lesson here is clear – when there are "low hanging cherries" that can be easily harvested, firms do not need government support to exploit these opportunities – the firms will be self-motivated to do so. However, synergies that require technical knowledge to exploit can benefit from external support.

This suggests that governments, or even independent networks such as the KS, that wish to see resources used in a more productive manner can seed the innovation process by providing the support that firms need to move beyond "low hanging cherries" to "cost saving investments" (Valentine, 2012). Support includes providing access to specialized knowledge, giving technicians within the firms time to think and providing incentives to pursue further initiatives. Support strategies might be as simple as hosting workshops to allow network partners to engage with industrial ecology experts to ferret out new profitable opportunities. As mentioned in this paper, such a strategy has worked well in Singapore and given the propensity of senior managers in Denmark to want to collaborate, it should stimulate innovation in Denmark.

Although delving deeper into specific strategies for revitalizing industrial ecology networks goes beyond the remit of this paper, planners should take heed of the main tenet arising from this research: Building a successful and sustainable collaboration network requires an awareness that these collaborations will eventually confront cognitive barriers to expanding the scope of collaboration and a formal commitment from network supporters might be needed to prod the network actors to elevate levels of collaboration.

The case study focus on Kalundborg sires the two main limitations of this study. First, because the study is context specific and the effectiveness of policy prescriptions tends to vary depending on the context (van Beers et al., 2009), it would be useful for future researchers to consider whether or not there are parallels between how relationships within the KS evolved and other industrial symbiosis contexts. Second, it would be valuable to expand the study to include other industrial symbiosis contexts in order to try and identify useful strategies for implementing Valentine's prescription of i) enhancing environmental management knowledge, ii) creating an environment that enables firms to collectively design innovative solutions to resource acquisition and disposal challenges and, iii) incentivizing firms to push themselves to higher levels of collaborative effectiveness (Valentine, 2012).

These limitations notwithstanding, it should be clear from this study that more proactive municipal financial support and engagement with the KS might just propel the Kalundborg Symbiosis to a new level of environmental governance. As Pike and colleagues point out, "realizing the potential of a disconnected world depends on building an infrastructure, both technological and human, that enables effective interaction" (Pike et al., 2005). Chertow sees the process of reconnecting with sustainability as a three step strategic path: "i) bring to light kernels of cooperative activity that are still hidden; ii) assist the kernels that are taking shape; and iii) provide incentives to catalyze new kernels by identifying precursors to symbiosis" (Chertow, 2007). In Kalundborg, it appears that the KS is already on that strategic path, but occasionally even the most resolute explorers need direction and a supportive shot in the arm.

## Acknowledgements

The author wishes to thank the City University of Hong Kong for financial support of this project (grant #7200392) and to Dr. Geng Yong and three anonymous reviews for helpful input into this paper. The author also thanks participants at the ISA Conference in New Orleans for feedback on an earlier draft of this research.

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