

INDUSTRIAL SYMBIOSIS

The case of Oman

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Sincerely,
Dariya Gavrish

Abstract

Current consumption and production cannot rely any longer on traditional linear approach to satisfy increasing needs of the growing population. Instead, the principles of circularity should be applied. One way to do is to adopt industrial symbiosis approach, which entails physical exchange of materials, energy, water and/or by-products between traditionally separate industries. However, the uptake of industrial symbioses is fostered not only by technical feasibility, but also social forces captured within the theories of the institutional capacity and intuitional context. Therefore, this research aims at understanding the influence of the institutional capacity and determining factors of institutional context on advancement of industrial symbiosis in the real-world application. For this purpose a case of an industrial park and port in Oman was studied. During the research process the link between uptake of industrial symbiosis and the local institutional capacity and context became distinct and undeniable. The result of the analysis became a range of proposed interventions and recommendations for Sohar Port & Freezone, which the actors could undertake, to boost industrial symbiosis. Moreover, it provides a good overview of the strengths and weaknesses of the institutional context, which shapes the range possibilities the actors of the park see there.

Key words: industrial symbiosis, institutional capacity, institutional context, Oman

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Executive summary

The world is experiencing rapid growth of population. It will result in rising energy needs. Such trends of consumption and production cannot rely any longer on traditional linear consumption patterns. Instead, a circular approach with the orientation on long-term sustainable development has to be applied. In Europe and China, one of the instrument towards achieving both resource efficiency and a circular economy is considered to be industrial symbiosis. Industrial symbiosis “engages traditionally separate industries in a collective approach to competitive advantage involving the physical exchange of materials, energy, water and/or by-products”. It can embed the approach of circularity of the resources and consequently limit the environmental impact of the heavy industries.

Therefore, under the spotlight of this research is the phenomenon of industrial symbiosis (IS). Literature suggests that for the development of IS the technical feasibility is not enough. What is also of great importance is social processes behind it: trust, commitment for collaboration, cooperation among stakeholders, mutual understanding of the common issues. Another defining factor, which shapes interests and decision of the actors with regard to IS, is the favourable institutional context. In the context of IS, it can be characterized by the alignment of interests between industries, government and institutions to support uptake of IS. The main example on which these two dimensions will be studied is SOHAR Port & Freezone, an industrial park and port situated in the Sultanate of Oman.

Thus, current research aims at understanding the influence of the institutional capacity on advancement of industrial symbiosis in the real-world application, which is SOHAR Port&Freezone. Secondly, it sought to comprehend the influence of the determining factors of the institutional context for the establishment and development of the particular case of Industrial Symbiosis. The central research questions that guiding this thesis are the following: 1) What are the strengths and weaknesses of the institutional context of the SOHAR for industrial symbiosis to evolve? 2) Which interventions of local actors will positively impact the institutional capacity of SOHAR Port & Freezone to advance industrial symbiosis?

Zooming in SOHAR, this industrial park is consisted of the several clusters. The ones that are in focus of this study are petrochemical, metal and utility. Looking through the lance of IS there are 4 main drivers identified for application of this approach: cost of the waste disposal, congested tenants' premises, economic benefit, concerns aboutreliance on the fossil fuels. The main challenges on the way of IS are the following: absence of support of re-use and recycling initiatives by Ministry of Environment and Climate Affairs in form of standards, incentives, guidance, time-consuming and complex procedure to obtain the permit for trials and implementation of the synergies. Moreover, the market is absent for some industrial waste streams consequently the actors are inexperienced to work with the secondary products partially due to the prevailing perception of “waste” as “waste“. Moreover, there is strong indication of the fact that the local waste management company is limiting the development of recycling and re-using practices. What was also recognized as a barrier is high availability of the relatively cheap fossil fuels, inadequate expertise of the main overlooking governmental authorities, prevailing unsustainable business models in the park, closed loop design of the plants that disables integration with another plant, low involvement of academia, which potentially can enhance development of IS.

The analyses part of the thesis contains identified enabling functions and roles for the uptake of industrial symbiosis within the park. To name a few important functions that are present in the park are: physical exchange of the secondary materials, building trust and commitment, provision of the critical mass of secondary waste streams, managing interactions and the social linkages between different actors, facilitation the connectedness among the actors ensuring their cohesion. Among the underperformed or absent functions are recognized the following: promotion of exchanges and eco-efficiency strategies, policy interventions, managing the stability in the network by recruiting new tenants or suppliers, setting up, communicating and enforcing long-term objective vision for sustainability.

In the course of this research several blocks of the institutional capacity were analysed such as relation, mobilization and knowledge, which resulted in the given recommendations for the interventions:

- Employ recruitment procedure for accommodation of the new tenants. Some tenants, e.g. construction companies can deliver benefits in terms of synergies either utilizing existing by-products in the park or offering beneficial ones. Give a priority to these projects, inform the commercial department.
- Appoint a steering group or person responsible for the identification, development and implementation of the synergies
- Discuss the synergetic opportunities already on the design stage with the new tenants since it is the very stage, when it is possible to make adjustments and enable technically the linkage. Make sure a water supply delivered by the water company for the new tenants to avoid new unnecessary desalination units.
- Capturing the economic benefits of the linkages.
- Encourage transfer of knowledge from Port of Rotterdam , where industrial symbiosis achieved significant progress.
- Formalize the platform for interaction. It has been noticed that there is lack of interaction between the tenants with the purpose of collaboration and solving common issues. Monthly meeting similar to HSE committee should be organized with the clear environmental agenda, where synergies can be discussed too.
- Revive the initiative of the “waste bank”. The idea is still very much in favour among the tenants. Encourage the tenants to create inventory of their waste and secondary materials, which can be of interest for other tenants. Create the website, where the tenants and other interested actors will have an access to the inventories (type / quality / quantity of materials).
- Carry out energy study to map out hot spots, waste losses and inefficiencies. There is very limited knowledge about it among the tenants.
- Compile the inventory of the secondary waste streams on the park level.
- Encourage and support formation of the industries associations (metal cluster), this is how the voice of the industries in dialogue with the Ministry of Environment and waste management company can be stronger.
- Share concerns about reliance on fossil fuels (with the help of platform for interaction). Encourage uptake of solar power. In fact, thermal solar power can generate significant amount of steam, which can be used by the industries. Stick to the vision and exercise more authority to push the sustainable agenda.

- Communicate the vision and create a strategy of its realization.
- Adopt sustainability goals and objectives.
- Collaborate more with the academia increasing the knowledge about practical possibilities and potential of IS in the park.
- Interact with overlooking authorities to motivate better regulations, which will force tenants to think seriously about energy conservation and efficiency.
- Improve of the enforcement system.
- Employ market based mechanism and regulatory incentives to promote energy saving and resource efficiency.
- Adopt guidance and standard for the recycling and reusing activities

Answering the second research question, the institutional context of Sohar Port & Freezone can be characterized by a number of strengths and weaknesses. Among the strong sides one can outline the following.

- Already existing cases of supply synergies and initial synergetic exchanges can serve as a foundation for the more sophisticated linkages and the experience to learn from.
- On-going process of solving the slag issue provides an evidence of the developing of institutional capacity and ability to solve the joint problem by formulation of the common challenge, development of an understanding, engaging the stakeholders and mobilizing the resources.
- Adopted vision to create an integrated industrial park that still to be communicated and realized.
- Presence of such enabling roles as champion, anchor and to certain degree the intermediary.

The weak sides of the institutional context are: underdeveloped market for the industrial waste products, under capacity of the Ministry of Environment, inadequate regulatory support of the resource efficiency measures, lack of standards and guidance of resource efficiency, absence of market-based instruments pressuring the companies to extract value from the secondary materials, strong perception of waste as “waste”, but not a “valuable by-product, prevailing business as usual approach not adopting sustainable business models. In addition, there is inadequate authority of TIWI, which is limiting the companies to consider and implement the synergies. No country sustainable objectives and market based and regulatory instruments employed in Oman.

Therefore, present research contains the study of the intangible forces behind implementation of the industrial symbiosis approach such as institutional capacity and institutional context. Knowing the leverage points, which this research gives a clue about, will help to boost industrial symbiosis in SOHAR Port & Freezone, embed circularity in operations. That would help to decrease environmental impact of the heavy industries and address relevant sustainability issues

Introduction

The world is experiencing rapid growth of population (FAO, 2009). The global urban population has been rising by an average of 65 million people annually during the past three decades (McKinsey, 2015). By 2050 the world's population will equal to 9 bln people, almost a third more than nowadays (FAO, 2009). As for the coming decades this trend will be largely associated with the higher consumption caused by the increasing incomes and purchasing power of people (McKinsey, 2016, TheEllenMacArthurFoundation, 2013). That can result in larger production and manufacturing in order to satisfy the rising demand of the planet (Topalli and Alagöz, 2014). As a consequence, the energy needs will also increase (Topalli and Alagöz, 2014). Some experts believe to as much as 50 percent more of the current needs (IEO, 2016).

Such trends of consumption and production cannot rely any longer on traditional linear consumption patterns ('take-make-dispose') (TheEllenMacArthurFoundation, 2013). Eventually it will lead to major inefficiency, scarcity, total depletion of resources (TheEllenMacArthurFoundation, 2013, Accenture, 2015). Instead, a circular approach with the orientation on long-term sustainable development has to be applied. In Europe and China, one of the instrument towards achieving both resource efficiency and a circular economy is considered to be industrial symbiosis (Qi and Wang, 2011, EURISA, 2013, Papathanasoglou, 2016). And indeed IS approach is mainly about the cyclical flow of resources through synergies with industries based on re-use of secondary materials, water, energy and so on (Chertow and Lombardi, 2005, Papathanasoglou, 2016).

Even though mainly exchange of the physical streams is concerned, to enable this synergetic process not only technological solutions should be in place. Intangible factors such as: trust, cooperation and commitment among involved actors is important. These and a number of other social factors are building so-called institutional capacity necessary to address development of industrial symbiosis (Innes and Booher, 1999). Therefore, this research is looking at the enhancing of the institutional capacity of one of the industrial complexes in Oman embedding the circular philosophy into its processes.

1.1 Problem definition

Initially the term of industrial symbiosis was coined more than three decades back in Denmark (Chertow, 2000, Zhang et al., 2014). Here in Kalundborg Eco-Industrial Park situated 100 km away from the Danish capital one of the first models of industrial symbiosis was successfully applied (Chertow, 2000, Bruck 2016). Symbiotic co-existence of such industries as petrol refinery, pharmaceutical factory, power station and gypsum plant has been evolving since as early as 1970 (Chertow, 2000, Lambert & Boons, 2001). The actors are sharing steam, fuel gas, electricity, residual heat and different types of water (Chertow, 2000, Lambert & Boons, 2001). Therewith significant environmental and economic benefits have been achieved (Chertow, 2000, Lambert & Boons, 2001).

The case has sparked the interest for the phenomena of industrial symbiosis on the levels of policy makers, academia and the business society (CECP, 2007). And as of now it is perhaps the most familiar example of industrial symbiosis (Lambert & Boons, 2001, Chertow and Lombardi, 2005, Zhang et al., 2009, Bruck, 2016). The first wave of the scholars of the industrial symbiosis was addressing mainly the technical side of industrial symbiosis (Yu, Davis, & Dijkema, 2014). The

focus was on the techno system, feasibility of the material linkages, closing the loops and overall technical feasibility whereas social aspects remained mostly unaddressed (Aparisim, 2010).

However, lately industrial symbiosis was regarded from point of view of process instead of a fixed state. It is a process that hinders or stimulates its uptake and development (Boons et al., 2011, Boons et al., 2014). It is when stakeholders and industries moving towards better integration, increasing institutional capacity, building the consensus, developing trust (Innes and Booher 1999, Baas and Boons, 2004, Boons et al., 2011, Boons et al., 2014). These are the social and organizational processes that play a vital role apart from the technological aspects in building up favourable institutional context for development of IS (Boons et al., 2014). By favourable institutional context one should understand the situation when “government, industries and other institutions are guided towards aligning their strategies in support of collaborative business strategies in resource management.” (Costa and Ferrao, 2010). Certain roles and functions can positively contribute into improvement of the quality of the institutional context, which will be thoroughly described.

Thus, the importance of intangible forces such as trust, commitment for collaboration, cooperation among stakeholders and other social processes were largely recognized in the literature (Gibbs, 2003; Hewes and Lyons, 2008; Posch, 2010, Boons et al., 2011). Researches became vocal about the idea that an ability to cope with the complex issues, which are of concern for the whole community, will heavily depend on the level of maturity of its institutional capacity and capability of consensus building (Innes and Booher, 1999). The concept of the institutional capacity encompasses these social forces that are responsible for the development and maturation of IS. Therefore, the more stakeholders invest in building and developing of the institutional capacity the higher the chances of successful initiation and implementation of the synergetic exchanges. Bhagavan and Virgin (2004) defined the process of building relation capacity as “... securing of the resources [human, technical and financial] and structures [relations, rules, values, behaviour] that are appropriate and essential for satisfactorily performing the functions (tasks) that the institution [universities, research centres, ministries, authorities, environmental organisations] is mandated to “

Thus, the central argument of this research is that developed institutional capacity is the critical factor for the uptake of industrial symbiosis and its main driving force. And in its turn, industrial symbiosis is the concept worth looking at due to being one of the approaches of circular thinking. And it also has potential to deliver significant environmental benefits. Therefore, dynamics and potential of the industrial symbiosis in particular case of an industrial park is going to be evaluated through the development of its institutional capacity.

The literature review showed that there is a gap of researching industrial symbiosis through the lenses of the institutional capacity in GCC region (Gulf Co-operational Countries). Therefore, this research carried out in the Sultanate of Oman will be of academic value. Another, inherited academic value of this research is deeper understanding of the influence of institutional capacity on advancement of industrial symbiosis in the real-world context. In this case, in the context of an industrial park SOHAR Port & Freezone.

From practical point of view the research also has a value for Oman itself. Arabian Peninsula accommodates the largest reserve of fossil fuels and is the biggest oil exporters. Despite all of it this part of the world is responsible for approximately 5 % of greenhouse emissions worldwide (EIA, 2017). However high reliance on the fossil fuels in the industrial production and high energy use

make the issues of the climate change very pronounced for the GCC region. And being signatories of the Paris Agreement it should push sustainable agenda and adoption of energy-efficient, innovative and sustainable practices.

In this way, industrial symbiosis can be a tool to address unsustainable energy and resource consumption patterns which are prevailing across the world including Oman (Chevalier, 2009, Qi and Wang, 2011, Hirschnitz-Garbers, 2016). Industrial symbiosis can help SOHAR Port & Freezone to embed the approach of circularity of the resources and consequently limit its environmental impact. Moreover, industrial symbiosis may allow SOHAR to make their operations more sustainable by applying circular thinking, energy and resource efficiency measures. Consequently, it can set the example for the whole region of applying innovative approaches leading to saving, efficiency and sustainability. It can change the perception in the region that linear approach in heavy industries is the only reasonable and accessible option.

The research will provide a range of recommendation for the involved actors on how to advance industrial symbiosis in the park. The challenges and strengths of the context will be also described, which will allow the involved actors to see the whole picture of the context, where they operate. Furthermore, the research will suggest some ideas about the areas of interest for potential synergies, which are worth looking at.

1.2 The aim of the research

Therefore, the aim of this research is twofold. First of all, it aims at better understanding the influence of the institutional capacity on advancement of industrial symbiosis in the real-world application, which is SOHAR Port&Freezone. Secondly, it sought to comprehend the influence of the determining factors of the institutional context for the establishment and development of the particular case of Industrial Symbiosis. Furthermore, this research aims at contributing into development of the institutional capacity of SOHAR Port & Freezone by a range of the meaningful interventions to support implementation of industrial symbiosis approach. The research is believed to encourage of the circularity in the operations and more sustainable way of doing things in SOHAR.

1.3 Research questions

Therefore, the guiding research questions for the current applied research will be:

RQ 1. What are the strengths and weaknesses of the institutional context of the SOHAR for industrial symbiosis to evolve?

RQ 2. Which interventions of local actors will positively impact the institutional capacity of SOHAR Port & Freezone to advance industrial symbiosis?

1.4 Scope and limitations

Regarding the scope, the focus of the research is a specific case of an industrial park of Sohar Port &Freezone. The park encompasses four major industrial clusters with tenants, however only three of them are included in the research. The reason being is that preliminary conducted research by the management of SOHAR did not show great potential of an excluded cluster (logistics) in terms of available by-products and materials for the synergies, so as required feedstock for its operations.

The current research also does not take into account to needed extent any technical and financial aspects of IS implementation. However, potential areas of interest for synergetic opportunities are going to be outlined.

Moreover, outside of the scope of the current research was left these synergies that are carried out on the basis of the regular commercial transaction and the exchanged products that have their inherited commercial value. These types of synergies are described as “supply synergies” and represent more “business as usual approach” rather than industrial symbiosis.

Talking about the contribution of this research to the development of the institutional capacity several limitations should be outlined. First of all, when it came to the interactions with some of the interviewees among the tenants, who agreed to support the research, they did not represent the top management level of the decision makers. That would probably give a different perspective on an internal policy of an organization and how the decisions about cooperation are made. Next to it, representatives of the senior management of the tenants have not been present during the final presentation of the research findings and discussion. However, talking to senior operation chiefs helped to dig a little bit deeper into practical potential of developing certain linkages. A number of opportunities have been mentioned by them and discussed during the interview. And after consulting the literature these opportunities have put on the map of the potential synergies. Secondly, with concerning the contribution to knowledge capacity the attempts were taken to look for the specific linkages between the tenants, which senior management might be not aware of. Even though the opportunities have been identified, they have not been sieved through the sieve of the critical success factors: convincing business case, proven technology and stakeholders’ approval.

1.5 Audience

Moreover it aims at creating new knowledge on two major levels: academic and practical. Academia will benefit from exploring the application of the IS concept in the Middle Eastern context in the specific case of Sohar Port. New created knowledge will comprise among the rest the investigation of evolution process of IS, study of determining factors for its establishment in the given case. As for the stakeholders of the Port of Sohar, after a thorough analysis they will be provided with the recommendations on how to improve the current state of the institutional capacity. On top of that, the outcome of the paper will be the guidance on how to bring industrial symbiosis further, what are the sensible interventions that will boost the synergies further

1.6 Disposition

To navigate the reader through the report, the structure of the report is described below.

Chapter 1 describes the reason to conduct this research, the problem that stands behind it and the aims and objectives it pursues. It also talks about what this research is not going to entail.

Chapter 2 presents comprehensive literatures review giving a thorough description of the theoretical constructs used in the research, including the concept of industrial symbiosis and institutional capacity. Moreover one can get familiar with the current academic body of knowledge. It lays a good foundation for further practical findings and analyses of the case.

Chapter 3 holds the explanation about the used research design and methods that helped to guide the whole research process and arrive to the conclusions and recommendations.

Chapter 4 presents SOHAR Port & Freezone, the place where the research took place. It gives the overview of the industrial park and the clusters that are located there. Then it talks about the drivers and challenges for the development of industrial symbiosis for SOHAR.

Chapter 5 contains analysis about the current state of the institutional capacity, including relational, knowledge and mobilization block. Next to it, it describes the institutional context with found enabling roles and functions for the uptake of industrial symbiosis.

And finally Chapter 6 provides answer on the research questions stated in the beginning of the work that guided the whole research. The reader can also find the recommendations for the development of the institutional capacity and consequently industrial symbiosis in SOHAR. On top of this, based on the findings two maps of the existing and potential synergies in SOHAR have been drafted and included in the chapter.

2 Literature review

For the further field work it is important to get to know most recognized potential barriers, drivers and benefits, to learn from the existing cases. Since the concept of industrial symbiosis is in its infancy in Sohar Port it is important to get familiarized with determining factors and characteristics of the enabling context, where it may arise and flourish. This section contains description of the core concept for this research, which is institutional capacity. Moreover, the reader can familiarize himself /herself with enabling power of institutional capacity and institutional context for the development of industrial symbiosis.

Definition

There are numerous definitions recognized in the literature, but perhaps the most common definition that was found is formulated by Chertow (2000): “[industrial symbiosis] engages traditionally separate industries in a collective approach to competitive advantage involving the physical exchange of materials, energy, water and/or by-products”.

Therefore, the bottom line of the numerous definitions is that industrial symbiosis suggests physical exchange of materials and by-products with consequent positive environmental and economic impact between the stakeholders in geographical proximity.

Furthermore, literature review has identified a lot of synonymous terms similar to industrial symbiosis. In order to avoid confusion between these other inter-changeable terms have to be outlined: regional resources synergies, regional industrial recycling, eco-industrial parks, green twinning, by-product synergy or eco-industrial development, industrial recycling network etc. Industrial symbiosis is also considered as a place specific practical application of such greater scientific field as industrial ecology (CECP, 2007). For the sake of research focus the paper will focus exclusively on industrial symbiosis in heavy industries per se.

Types of synergies

Got familiar with what industrial symbiosis stands for the next step is to understand what it can entail. There are two approaches to define synergy types. On a general level, as proposed by Van Beers et al. (2007), one can consider “by-product exchange” and “utility synergy”. Therefore, not only exchange of the secondary materials, but also sharing the utilities can account for industrial symbiosis. Typical example of the shared utilities is water, waste and heating infrastructure. A major study carried out by Center of Excellence in Cleaner Production (2007) revised 167 synergy projects in 22 regions around the world. The graph below represents the most common types of synergies, where exchange of the process waste is a dominating category.

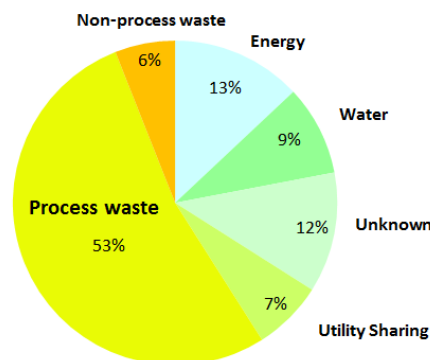


Figure 1. Common types of synergies Source: Adopted from CECP, 2007

As it can be seen the biggest category account for exchange of the process waste, which includes different types of waste generated directly from manufacturing. The second biggest category is exchange of energy. That can be, for example, both co-generation of energy and channeling the waste heat to some other recipient from the company it produced. When it comes to water, the tenants can recycle the process water putting it back to cycle; waste water can be used for cooling or preheating purposes. Utility sharing stands for the joint use of infrastructural amenities such as, for example, water treatment, energy and heat supply. And finally the non-process waste, which is generated during the small scale activities associated with routine processes.

Another type of synergies recognized in the literature supply synergies (Van Beers, 2007). These are the synergies of the principle feed-in products for the core operation of an industry. The main driving force behind is co-location of the actors and should be considered as “business as usual”.

Benefits

It is crucial to learn about potential benefits since it can be used for the promotion of IS concept among management of the SOHAR port and encouraging local buy-in. In fact, a lot of attention in the literature is drawn to this topic including positive impacts of industrial symbiosis (van Leeuwen et al., 2003, Gibbs et al., 2003). Identified in the literature benefits can be grouped in seven major groups, which is represented on graphs below.

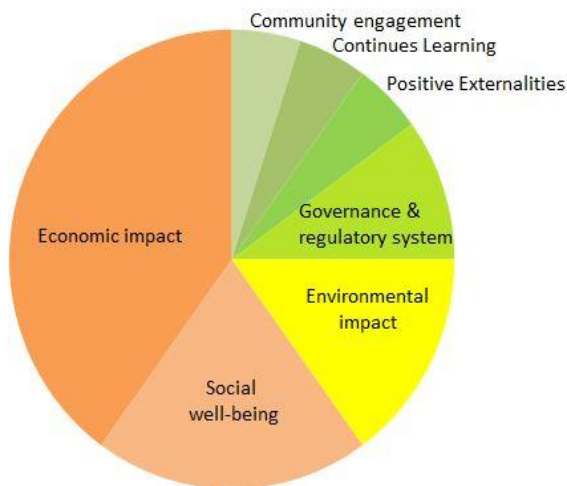


Figure 2. 7 areas of the benefits of IS

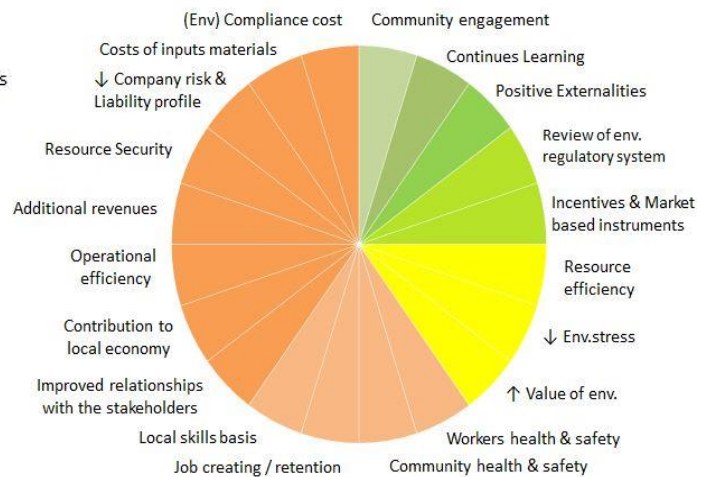


Figure 3. The whole list of the environmental benefits

- Economic impact.** It has been proved that reduction of input material results in financial savings for the involved companies (Chertow and Lombardi, 2005, Chertow & Miyata, 2011, Guo et al., 2016). Furthermore, the company can earn revenues on excessive energy it produces, waste and water it generates if it can be of value for another company for its processes. And from the point of view of the recipient company it can avoid transportation fees or get the feed-stock at discounted price and increase security of the access to the materials (Chertow and Lombardi, 2005). In case this exchange is possible and viable that can add flexibility and efficiency to the certain processes. Continuing on the financial side decreased amounts of waste and water that needs to be treated and disposed means avoided costs (Chertow and Lombardi, 2005, Chertow & Miyata, 2011, Guo et al., 2016). That can be achieved through circulation of byproducts, re-cylce and re-use.

- **Environmental Impact.** Overall emission reductions in the air, effluent and waste discharges can significantly reduce the burden on environment and nearby ecosystem. Some of these avoided burdens are, for instance, acid precipitation, acidification and eutrophication (Yu et al., 2015). Given the main feature of IS is that by-product and waste of one company become a feedstock to another, considerable resource efficiency can be achieved and the landfill space saved (Chertow & Miyata, 2011). That can lead to overall reduction of extraction and production of raw materials and energy, uptake of re-use and recycling (Sokka et al., 2010, Chertow & Miyata, 2011, Guo et al., 2016). And overall reduction of greenhouse emissions (Chertow & Miyata, 2011, Yu et al., 2015).
- **Social well-being.** There could be also a positive impact on workers' health and safety so as communities nearby. As an example, avoidable toxic and dangerous water and waste discharges are captured and found a proper application for. Furthermore, development an industrial complex can bring the expertise and skills of the local workers and management on a new level by absorbing new knowledge and best practices (Fric, 2015). And establishing and keeping these synergies going to open the prospects for the new job opportunities (Ometto et al., 2007).
- **Governance & regulatory system.** Collaboration between corporate sector, industries and authorities may foster design of the right incentives and policies to boost development and implementation of symbiotic exchanges (Costa et al., 2010, Papathanasoglou et al., 2016, Wang et al., 2016). This point is especially valid for the cases, where IS concept is driven by the government as in a lot of Chinese examples (Wang et al., 2016). Costa and colleagues (2010) pointed out certain mechanism that should be in place to encourage the companies to go beyond compliance and encourage IS. These are: national objectives and targets, strong economic and regulatory instruments (e.g. landfill taxes and bans), regulated quality and of technological treatment standards (Costa et al., 2010). This is when government is responsible for creating the right institutional context. However, commonly regulatory signals send by the government are influencing the evolution of IS rather than evolution of IS is impacting the legislation (Zhang et al., 2014).
- **Community engagement.** Industries, companies and authorities can gain substantial support and approval for the developments among local communities by proving the evidence of the social and sustainability commitment (Ometto et al., 2007). In perfect case scenario, local communities will have a say in the developments in the industrial parks if they are impacted with it. For instance, if there are settlements in vicinity of the industrial zone people can witness unsustainable burning practices such as flaring of gas. If their complaints reach the local authorities and these will take certain actions to address them the industries might be pushed to apply more sustainable practices and, for example, use the flare for heat or power purposes.
- **Exchange of experience and best practices.** Industrial Symbiosis provides a platform for constant learning, exchange of experience and best practices. One of the reasons is there is

hardly any ceiling for the potential improvement in such a vast clusters as industrial parks (Innes and Booher, 1999).

- **Motivation of innovations**

In fact, the literature says that industrial symbiosis has an ability to motivate innovations (CECP, 2007, Mirata and Emtairah, 2005), which eventually is paving the way to sustainable development. It is argued that building the synergies critically relies on “new” infrastructure to capture, transport process and use as a feedstock (CECP, 2007). Furthermore, while searching ways to reduce environmental impact the industries industries might align their innovation activities, which will result in improvement of regional innovation capacity (Mirata and Emtairah, 2005). The authors also note innovation can be achieved through inter-organizational collaboration and learning, which is also developing knowledge and relation capacity.

Therefore, industrial symbiosis can positively impact, first of all, micro and macro level of the business environment of an industrial park. And secondly it delivers significant environmental and social impact contributing to the sustainable development.



Barriers

It is important to foresee and recognize potential barriers hindering the uptake and development of industrial symbiosis. There are five major categories of barriers that are well described in the literature (Brand et al., 1999, Costa et al., 2010, Mäkelä et al., 2012, Pajunen et al., 2012, Watkins, 2013, Watkins et al., 2013, Walls and Paquin, 2015).

Figure 4. Barriers for the development of IS

Institutional barriers appear to be one of the most relevant for the field research. Therefore it deserves to be discussed in more details among the first barriers. To begin with one of the possible institutional barriers is that relevant ministry or authority has not provided yet incentives or financial benefits for the business sector to advance implementation of synergies (Costa et al., 2010, Papathanasoglou et al., 2016). Moreover, there can be absence of the national sustainable targets, objectives and commitment announced by the government, which consequently results in absence of guiding policies to encourage uptake of industrial symbiosis (Costa et al., 2010).

Furthermore, there can be lack of overarching guidance on material recycling, resource re-use and required efficiency, compliance criteria of these practices (Pajunen et al., 2012). As a consequence another widely discussed barrier in the literature is definition of waste and individual waste categories. The problem is that waste is regarded as refuse and garbage rather than as a by-product. And the process of removing this status has been discussed in a number of publications (Costa et al.,

2010, Mäkelä et al., 2012, Pajunen et al., 2012, Watkins, 2013, Watkins et al., 2013). It appears to be very time-consuming and expensive process for the involved parties, which eventually diminishes the motivation of actors for sustainable initiative (Mäkelä et al., 2012, Pajunen et al., 2012, Watkins et al., 2013). Continuing about the waste issues another institutional barrier highlighted in the literature is inadequate support for the material tests and research on synergy products (Pajunen et al., 2012). However, often times these tests and researches are paving the way for the synergies to be established.

Regulatory barrier usually appears in form of restrictive environmental regulations, which are not flexible enough to enable exchange between the actors (Brand et al., 1999) or this regulation is really limited or not in place at all (Papathanasoglou et al., 2016). For example, Watkins and colleagues (2013) discuss lack of guidance on practical implementation of life-cycle thinking and ways to avoid landfilling. Suggested reasons for these shortcomings enabling industrial symbiosis the same author explain with the absence of political will and long-term thinking.

Another unfavourable factor could be challenges with obtaining approval for alternative application of waste. Literature review has shown that this issue were experiencing the companies in one of the famous cases of industrial symbioses in Kwinana, Australia. Despite economic and technical feasibility and obvious environmental benefit there were obstacles on getting approvals for the alternative application (Van Beer et al., 2007).

The author also points absence or inadequacy of standards for the re-use of materials and recycling (Pajunen et al., 2012, Watkins et al., 2013). On the other extreme, environmental regulation can be so strict that it might significantly increase management costs of the by-products, which makes the exchange not economically viable or the actors might face substantial bureaucracy in their attempts to establish cooperation (Papathanasoglou et al., 2016). And finally certain materials cannot become an input for another company due to quality not high enough to meet the requirements (Brand et al., 1999).

Organizational barriers refer to the constrains within the organization itself to build collectively aligned flows of tangible and intangible materials and resources (Fric, 2015). The author in her work distinguishes four main organizational barriers: trust, cooperation, flexibility and creativity (Fric, 2015). Absence of trust can increase transaction costs, risks, exchange insecurity which are so critical to build up collaboration (Ehrenfeld Gertler, 1997, Chertow, 2007, Domenech 2010, Fric 2015). Another barrier is the absence of embedded culture of cooperation in the organization. Which means management is not willing make efforts for the sake of collective success. The reasons for it could be protectiveness of the business know-how (Watkins, 2013). Absence of flexibility is related to the previous factor and entails inability of organization to adjust to changes and signals coming from internal and external environment (Regev et al., 2007). And finally lack of organizational creativity might result in being non-receptive to new approaches and ideas, including sustainability, life-cycle and so on (Fric, 2015). The last two barriers could be due to common mentality of management “not my core business” (Watkins, 2013). Talking about the roles which can be observed in the integrated complex, absence of some might pose a significant challenge for further evolvement of IS. For instance, if the park leaves the tenant, which provide critical mass of energy

and resource flows for the synergies in the park to evolve. Or another example is can be seizing the function of the certain personnel responsible for developing the synergies (Walls and Paquin, 2015).

Among organizational barriers other points could be mentioned too: lack of trust, commitment, unwillingness to go beyond the corporate boundaries, non-alignment of visions and interests between stakeholders (Walls and Paquin, 2015). Established synergies may also result in dependency creating asymmetry between the power and control among the actors and uneven distribution of gains (Walls and Paquin, 2015). Another problem is recognized to be risk aversion among the industrial and consequent reluctance to invest in unproven technology (Moors et al., 2005, Pajunen et al., 2012). In addition to that there is an important mental barrier. Actors do not realize they have an opportunity to choose and change their traditional business model, therefor business-as-usual remains to be answer to all arising questions (Pajunen et al., 2012).

Technical obstacle refers to inability to find a user for the by-products of a company or technical incompatibility of the waste streams. The shortcoming that has been observed in the literature is the inconsistency of materials or energy flows and related expectations concerning their quality (Costa et al., 2010, Walls and Paquin, 2015). And even though the company might be ready and open to market their by-products and resources, the sub-contractor or the market might be not there (Watkins, 2013). In this case the materials either discarded or even sent abroad if there is a market.

Information barrier arises when there is no available knowledge about the potential market for by-products or alternative options for the input materials (Brand et al., 1999). What also can happen is that the residents of the same park have very limited knowledge about inventories of other tenants, which potentially could be of interest. Absence of knowledge about alternative waste management options and materials substitution could become a barrier too (Costa et al., 2010). Poor monitoring of the synergies is also noted as an impeding factor for development IS (Walls and Paquin, 2015).

Economic barrier refer to such instances that can be described as too costly, economically non-viable, risky, high uncertainty, poor reliability of demand and supply. On top of that it might be not sensible to invest in shared utilities or infrastructure due to lack of economy of scales or too large geographical distance between actors (Brand et al., 1999).

Critical success factors

There is a valid question what distinguishes an ordinary industrial cluster from the eco-industrial park. And next to that how one can grow into another and what are the factors and enabling mechanism foster that transition.

Looking at this issue a number of authors (Boons et al., 2016, CECP, 2007; Chertow, 2007; Korhonen et al., 2002) suggest that in a lot of cases the reason for the development of industrial symbiosis is the result of self-organization and spontaneous development fostered by evident economic benefits. Initially the process does not have an ambition to develop a synergetic network (Boons et al., 2016). On the contrary, the emergence of convincing business case is enough to catalyze the synergetic exchanges. Authors give the example of the most iconic Kalundborg case along with the number of othes including Styria (Austria), Kwinana (Australia), Nanjangud (India) etc. They underline the fact that IS emerged in Kalundborg without any preliminary planning or

developed vision, but mainly due to substantial benefit of alternative way of waste minimization (Korhonen et al. 2002).

However, Van Berkel et al. (2005) argue this point of view and define three **critical success factors** to establish synergetic exchanges, without which industrial symbiosis is not likely to happen. This framework appears to be useful for identification of the viable synergies and in Sohar Port and Freezone.

- **Convincing business case** refers to the economic benefits of industrial symbiosis. Therefore such conditions should be fulfilled as significant cost reductions, decrease of the company risks and liability profile or / and increase of the operational efficiency. Another driving force would be generation of the revenue streams and securing the access to the critical resources and materials (Van Berkel et al., 2005, Van Berkel 2006, Corder et al. 2006).
- **Stakeholders' approval** is another essential prerequisite for the success. Such stakeholders as authorities, business and perhaps the impacted communities should demonstrate support, trust and commitment.
- **Proven technology** speaks for itself – a proper technological solution should be found to ensure unhindered exchange of by-products, energy or materials between the participants (Van Berkel et al., 2005, van Berkel 2006).

Institutional capacity

Having described the concept of industrial symbiosis it is time to focus on the social processes responsible for its emergence and development. One of the central concepts that encompasses the social dimension, and mainly responsible for the dynamics of IS, is institutional capacity (Boons et al., 2011). This concept refers to ability of social systems to solve collective problems and common issues (Innes and Booher, 1999). A very comprehensive definition was given by the previous authors “an array of practices in which stakeholders, selected to represent different interests, come together for face-to-face, long-term dialogue to address a policy issue of common concern” (Innes and Booher, 1999). Basically, institutional capacity can be also described as a product of interaction between members (Spekkink, 2013).

In the context of industrial symbiosis the concept of institutional capacity was well described by scholars Boons and Spekkink (2011, 2012). The main idea behind the concept is that in order to launch a successful joint project stakeholders need to find the common ground, develop the trust that enables collaboration, arrive to the shared strategic vision and mobilize the resources.

Generally the literature distinguishes three building blocks of institutional capacity (Healey et al., 2003, Boons and Spekkink 2012):

- Relational – reoccurring interactions between the stakeholder with the aim to address the common concerns and the result of developing trust and commitment ;
- Knowledge – the ability of stakeholders to obtain the information and to share it between each other;
- Mobilization –the ability of channelling the resources for realizing certain initiatives (Boons and Spekkink 2012);

Relational capacity is perhaps the starting point to work upon if industrial symbiosis is chosen to be a course of development. Relational capacity is meant to help with the search of new solutions for resource and energy efficiency, communication the same message through the whole value chain (Ceglia, 2017). Since IS refers to engagement of traditionally separated industries, relational capacity and interactions are these forces that will bring these industries together. Scholars manifest the idea the stronger is personal and professional relationships, trust between the actors, mutual confidence and understanding the more probable that it will help them too see the opportunity, to realize the common issues and proceed to its settlement (Healey et al., 2003, Spekkink, 2013). Moreover, good personal relations are reducing the risk of the transactions between the companies (Elster, 2007).

The importance of the knowledge capacity resides in sharing knowledge that would help the actors to obtain better perspective of each other's interests, coordinate the mutual efforts, and come to the mutual denominator about common issues avoiding the conflicts (Boons and Spekkink 2012). Moreover, this kind of capacity also talks about the ability to come up with needed data, day-to-day experience, and practical knowledge and circulate it among the actors to coordinate the actions and utilize for the common purposes (Innes and Booher, 1999). Sharing of knowledge can also uncover potential linkages and help to judge their feasibility (Elster, 2007).

Mobilization capacity enables actors with the adequate resources and influences to mobilize the rest of stakeholders to implement synergies and increase the integration (Spekkink, 2013). Moreover, with the help of the previously mentioned relations and knowledge aspects mobilization capacity encourages the actors to engage in new practices and ventures (Ceglia, 2017). This capacity can also allow influencing relevant policies and regulations to enable IS (Elster, 2007). Therefore, described three dimension of the institutional capacity are supporting the argument that it is not enough to have technical and economic feasibility of the exchanges (Gibbs, 2003, Posch, 2010).

Furthermore, according to Boons and Spekknik (2012) there are several conditions in which IS is likely to occur. One of these is favourable institutional context, which encompasses "policies and regulations (governance context), geographical and infrastructural restrictions (physical context) and market developments (economic context)" (Spekknik, 2013). Depending on these components of the institutional context the actors will see certain possibilities and different course of actions (Spekknik, 2013). Institutional context is one of the central categories for this research and will be closely examined for SOHAR Port & Freezone.

Talking about the process of building institutional capacity a very important process of social learning has to be mentioned. According to Innes and Booher (1999) this process is the far-reaching effect of building the institutional capacity. Nevertheless, social learning describes the process during which different actors (e.g. policy makers, authorities, industries) are brought together to learn about how to arrive to common consensus and solve the complex problems collectively (Kilvington, 2010). At this stage reassessment of the purposes and goals might take place so as interconnected nature of interest and issues. It is one of the initial stages of the development of the institutional capacity on the way to highly integrated eco-park. One of the challenges during this process is that the actors might go back to their old behavioural patterns; therefore it might be incentivised but not imposed by external actors such as authorities, local governments (Baas and Boons, 2004). What can enhance this process is good relation and knowledge capacity.

Process of the building of the institutional capacity distinguishes several steps (Spekkink, 2012). One of which is orientation of the actors. In that respect adoption a common vision for the industrial park is an important milestone in addressing an issue of common concerns. Besides this the vision outlines the direction for further interactions between the stakeholders, social learning process (Baas and Boons, 2004, Spekkink, 2012). Having the strategic vision the actors are more likely to start working together on common issues rather than autonomously (Baas and Boons, 2004). The presence of this vision to a certain degree indicates the commitment of the senior management to incorporate synergies into overall approach of the park management and its future development. Moreover, the vision might also mean stakeholders have shared understanding of the problems and solution, which are codified exactly in the vision (Boons and Spekkink, 2012).

Enabling mechanisms

Another meaningful contribution to the analysis of the enabling context and condition for industrial symbiosis has been done by CECP (2007). Three main groups of enabling mechanisms were identified in the course of the conducted research: **facilitating structures, operational and contractual arrangements and evaluation methods.**

- The first mechanism suggests that there should be some sort of actors or a group of actors that are playing a facilitating role for the process of industrial symbiosis. To give an example, it can be the leadership from the industry in form of association of industry representatives or the business themselves, government. Or within the park there is an appointed working committee, steering and advisory group that foster IS or even the tenants themselves if there is a certain pressure. Next to the actors of importance are also the key activities enabling IS: funding including investments, promotion and channelled communication and synergy development identification workshops, compiling of inventory database.
- Importance of operational and contractual arrangements refers to the basics of IS – exchange of by-products, energy, water and shared use of utilities (Chertow et al., 2004, CECP, 2007, Vito et al., 2016). Unless it is top-down approach, which means IS is imposed by the overlooking authority, contractual agreement forms a foundation for self-organized manner of pursuing IS benefits (Vito et al., 2016). There can be bilateral agreements, agreements for the support of service providers (water treatment, waste management) etc. Even though the exchanges might be formalized between the companies, still the role of trust is crucial in here, enhancing the efficacy of the contract (Lambert and Boons, 2002, Vito et al., 2016).
- Such aspect as “commercial proximity” should not be left without attention talking about enabling context. This term means that the partners are willing to contribute funds to transfer the materials (Branson, 2013). The author argues that making the decision about the partner for exchanges holistic commercial perspective plays a bigger role rather than just financial or geographic factors alone (Branson, 2013).
- Another important element, which can mobilize principles of industrial symbiosis is effective application and of sustainable business models. In fact, there is growing body of literature linking the themes of industrial symbiosis and sustainable business model innovation (Chertow 2000, Bocken et al. 2014, Short et al., 2014). The starting point here is that a company besides its core business can upgrade the business model and offer a wide range of additional synergistic and profitable product lines (Short et al., 2014). Apart from this the central

theoretical framework here describes three levels, which should be considered while creating a new business model:



Figure 5. The model of the sustainable innovative business models

Source: Adopted from Osterwalder et al. 2005; Richardson 2008

Moreover, Bocken and colleagues (2014) summarized found in the literature the courses of actions, which companies should follow and make a foundation for sustainable business model. The most relevant of them for this research are: “maximize material and energy efficiency; create value from waste; substitute with renewables and natural processes; adopt a stewardship role; encourage sufficiency” (Bocken et al., 2014).

- And final enabling mechanism is keeping the account for the economic, environmental and social benefits that synergies are delivering (Chertow and Lombardi, 2005, Kurup, 2007, Van Berkel 2010). If Industrial Symbiosis is relatively new phenomena for a park and is on early stages of its development the account of economic benefits can be deployed at the first place. And on later stages of the development social and environmental mechanisms may become in focus too.

And rounding up the overview of the determining factors for IS outlined in the literature one cannot miss work of Boons and Spekkink (2012) and Baas (2005). It argues that that the parks with high level of information, relation and mobilization capacity are most likely to catalyze the wider uptake of industrial symbiosis. Moreover, critical conditions have not been mentioned so far, but play an important role:

- the time required for the learning process to ensure that the actors will not get back to the old ways of doing business (Boons and Spekkink, 2012). Learning process as a far-reaching effect of the institutional capacity has been described earlier. But what is important is to keep in mind that it’s a lengthy process that needs a lot of dedication;
- not too high diversity of the participants to ensure wide range of by-products offered for the exchange, but prevent the point of the conflicting interests (Korhonen and Snäkin, 2005). The authors argue that the more participants are involved the more possibilities for cooperation are there. However, at the same time it also means an increase in the number of interests and preferences, which might result in the conflict of interests and prevent industries from connectance and interdependency (Korhonen and Snäkin, 2005).

Before proceeding to the last major part of the literature review some other source of inspiration for future recommendations should be outlined. UNEP document “Recommendations for

Management of the Industrial Estate” came to become useful for the purpose of this research. The document comprises the recommendations on how to incorporate Environmental Management System, encourage uptake of ISO certification among the tenants, how to promote cleaner production (UNEP, 2001). Most importantly, it discusses the approach of industrial ecology and by-products synergies. Even though the guideline is dated from 2001 and over this time industrial symbioses became even more mature over the world, this approach still received such a serious recognition on the level of such an organization.

Enabling roles and activities

One more lense, through which enabling contextual conditions can be viewed, is a set of roles and activities that certain actors can perform and thereby foster synergetic exchanges. This part of the literature review will have a value for the practical part of the research since these roles are capturing and trying to explain the complexity of the real-life context associate with the large volume of variables. Looking at the below described role can help with conceptualization of industrial symbiosis as a process (Sun et al., 2017).

Therefore, literature review has helped to identify several conceptual roles that are responsible for creating local and institutional conditions that can motivate the uptake and development of industrial symbiosis. However, looking critically at these roles significant overlap can be noticed in functions these roles perform. Therefore, more reasonably is to look at them from perspective of functions the roles provide. The summary of the functions is presented in the table below:

Table 1. The list of the enabling functions

The list of enabling functions
Policy interventions
Monitoring the markets
Encouraging local buy-in
Resolution of the conflicts
Carrying out feasibility studies
Building trust and commitment
Physical exchange of the secondary materials
Ensuring well-functioning of the present actors
Managing non-core businesses of the companies
Providing managerial and infrastructural support
Promotion of exchanges and eco-efficiency strategies
Identification of potential IS synergies and partners for it
Obtaining and sharing knowledge, provision of educational services
Creation and facilitation of local physical and institutional conditions
Managing interactions and the social linkages between different actors
Facilitation the connectedness among the actors ensuring their cohesion
Managing the stability in the network by recruiting new tenants or suppliers
Pulling together the dispersed resources and capabilities of network members
Setting up, communicating and enforcing long-term objective vision for sustainability
Provision a critical mass of resource and energy flows for symbiotic linkages to evolve

Anchors. One of the widely recognized enabling roles in the literature is anchoring. Sun et al., (2017) define it as “activities that (typically local) actors perform to create local physical and institutional conditions” to foster emergence of industrial symbiosis. The Authors define two types of anchors: industrial and institutional (Bürstrom and Korhonen, 2001, Sun et al., 2017).

Industrial anchoring is an example of self-organization process between industries based upon evident economic benefits (Boons et al., 2017). Industrial anchors are a couple of key actors, who provide a critical mass of resource and energy flows for industrial symbiosis to evolve (Boons and Spekink, 2012). These can be both tenants in the park represented by the companies. When it comes to industries, usually anchors provide large amount of materials and energy flows, utilities, services for the whole park area.

With regard to institutional anchor, these do not provide any critical mass in terms of material flows, but rather create the right conditions and context for industrial symbiosis to thrive. Among the key roles of the anchor the following can be highlighted: stimulation of interaction between stakeholders, obtaining and sharing the knowledge and expertise, ensuring political and managerial support, recruiting the tenants and actors (Sun et al., 2017).

Brokers. Brokers are the intermediate agents, who are responsible for facilitating the connectedness among the actors ensuring their cohesion by shortening the distances between them (Aparisi, 2010). Their function might entail the following: identification of potential IS synergies including its technical and economic feasibility, identification of potential IS partners, promotion of exchanges, spreading the necessary knowledge and information, monitoring the markets, facilitating cohesion of the network (Massard and Erkman, 2007, Aparisi, 2010).

Mainly the literature distinguishes 3 types of intermediaries: knowledge, relation and service. Knowledge broker transfers knowledge between different stakeholders within the network and / or identifies these resources (Krenz et al., 2014). In other words, they are responsible for obtaining, sharing knowledge. One of the examples for the knowledge intermediaries recognized in the literature is non-profit organizations (Chongfeng et al. 2009). That, for instance, can be academia represented by researches, who can contribute into development of industrial symbiosis by expanding knowledge capacity. Thorough analysis, defined cause-and-effects links can support decision making process and thereby contribute to value creating structures (Krenz et al., 2014). Hence, such actors can facilitate symbiosis providing useful knowledge and information to management and decision making stimulating thereby new policies. Massard and Erkman (2007) point out that brokers should also inform economic agents the issues related to exchange of secondary materials and resources efficiency to promote the circularity of resources.

Relational brokers are managing interactions and the social linkages between different actors in the network. The main goal of the brokers in this case would be, as specified above, to ensure relational cohesion, resolve the conflicts impeding cooperation and mutual understanding, and bridge the communication gaps.

Champions. One of the vivid examples of the role of the relational broker is so called champion. The importance of the presence of the steering committee as a predetermination for industrial symbiosis to evolve has already been mentioned earlier. It was suggested that developing a strong social networks is one of the enablers for the whole process (Aparisi, 2010, Zgang et al., 2012).

However, Hewes and Lyons (2008) argue that there is more to it and close personal relationship and human connections are of great importance. Eventually these very connections might grow into networks and will serve for the project teams responsible for the symbiotic exchanges (Hewes and Lyons, 2008). Sakr et al. (2011) adds that cooperation between the companies and actors is hardly possible otherwise and cannot be mandated through any policy interventions; therefore the role of champion is highly valuable. Similarly to the roles described above champions can be either a company, institution or a local leader. The task of the champion is to bring people together, inspire them, encourage local buy-in and as a result create a committed project team (Hewes and Lyons, 2008). Generally the driving forces for these kinds of relationships are trust, support of the community and finally proximity meaning that leaders are as close as possible to the ground of the project.

Continuing with the different types of intermediaries service-intermediary should be mentioned next. When it comes to this actor one can think of physical exchange of the secondary materials. One of the examples could be utility companies, which provide water services, compressed air, gasses and energy. For instance, if by-products cannot be used without additional treatment or adjustment then the intermediary can be of help. Intermediaries are facilitating these processes being represented by the waste management companies. Therefore, following distinguished roles of scavengers and decomposers are falling into this group of service-intermediary. The importance of the service intermediary is hard to overestimate since they ensure flawless operation of the industries.

All in all brokers might provide favourable institutional conditions for the development of IS and improvement of institutional capacity. These can include: policy interventions, managerial support, educational services and infrastructure support (Gibbs and Deutz, 2007). The actor, who can perform these roles, might be, for example, the local authorities or industrial estate authorities (UNEP, 2001).

Scavengers and decomposers. Earlier in the paper the linkage between natural and industrial ecosystem from perspective of industrial symbiosis has been discussed. As known in the nature there are several links in the food chain such as producers, consumers and the last but not the least scavengers and decomposers. The same applies for the industrial symbiosis system. Among the roles, which different actors might play, scavengers and decomposers have an important function such as help with waste collection, recycling, repair, reuse, remanufacturing, close the loops (Geng and Côte, 2002). Both of these roles are very important both from environmental and economic points of view. Firstly, it decreases the environmental impact of generated waste and secondly, and it adds the value to the materials that otherwise would be discarded.

Scavengers are these companies, which are leaving off the waste of other companies. A good example is a waste collection company, which are redistributing resources to the companies that can (up)-recycle and process the materials. The key feature in their function is that scavengers are not consuming the materials as such. They just dismantle, crash, sort, refurbish and transport them for the end user (Geng and Côte, 2002).

Decomposer, on the contrary, utilizes secondary materials supplied both directly from the producers or scavengers in their own production. They are dealing with the breakdown of the materials, therefore remanufacturing, reuse and refurbishment is mainly the task for the scavenger company

(Geng and Côte, 2002). An example in the industrial park could be sludge treating company producing fertilizers.

In practice, the greater the diversity of the waste streams available for the both actors, the lower is the risk for the whole system (Setchi et al., 2016). It is much safer if the companies rely on several waste streams and diversify the risk of supply. Therefore, that can serve as a good indicator for the functioning of the IS system. Furthermore, as pointed out in the literature the higher the number of operating scavengers and decomposers in the park, the more resilient the system will be. That is achieved due to greater availability of the different alternatives for the input-output materials (Côte and Smolenaars, 1997). However, it should be noted that sometimes instead of looking for the synergy in the park the company rely on scavengers depriving the tenants of the opportunity to make use of the resources that are going out of the park.

Orchestrators Dhanaraj and Parkhe (2006,) define orchestrator as an actor, who "... uses its prominence and power to perform a leadership role in pulling together the dispersed resources and capabilities of network members". In other words it means that the orchestrator without owning the assets and capabilities empowering the actors in the network and integrating the processes around symbiotic exchanges. Moreover, orchestrator encourages actors such as managers and suppliers in the network to act more entrepreneurially (Saloluoma, 2014) and avoid rivalry that is an obstacle for symbiotic exchanges (Kleindorfer et al. 2009). The role of orchestrators can be performed either by an external or internal business network or even mentioned above champions, anchors or brokers. If it is an anchor company then the prerequisite to become an orchestrator would be not only having a central position, but also many connections with other member of the network in and outside the park (Ryynänen and Patala, 2013).

There are a number of orchestrating roles identified in the literature. Among them are: sharing and mobilizing the knowledge, managing the stability in the network by recruiting new tenants or suppliers, ensuring well-functioning of the present actors; justifying the synergies for the companies; accounting of the benefits; promoting implementation of eco-efficiency strategies; building trust and commitment; managing non-core businesses such as exchange of the secondary materials and energy flows (Ryynänen and Patala, 2013). Therefore, from the range of activities it can be seen that it exceeds range of responsibilities of the single company and it is more of the team work.

Coordinators. And finally the function of the coordinator is going to be discussed. Even though coordinating activities can be performed by the number of actors described above, for instance, champions or brokers, it is worth doing to appoint a separate category. The main role of coordinators is to create a "playground" and provide the necessary support for development of IS (Aparisi, 2010). One of the main feature of the coordinator is that this actors have a long-term objective vision for sustainability (Mirata, 2004), which can be, for example, increase uptake of renewables in the region or reduce environmental impact from the heavy industries (Ellen MacArthur Foundation, 2013). What else these actors can do is to promote waste minimization practices in the park by introducing ISO 14001 standards and principles. It is regarded as main decision-making body having a lot of authority and power. This body is responsible for creation the right institutional framework that encourages the actors to cooperate (Aparisi, 2010). Among its functions are generation and mobility of knowledge, promotion of communication between the stakeholders, identification of potential synergies and support of symbiotic exchanges (Mirata and Pearce, 2006, Aparisi, 2010).

Therefore, this section provided relatively deep insight of industrial symbiosis as a process with its driving and impeding factors. Reader got familiar with the key enabling factors and the condition of the institutional context that allow developing of IS. And finally, the significance of the chosen core theoretical concept has been described.

Coming back to the overarching theory of the research these identified role and activities can significantly contribute into improvement of the three levels of the institutional capacity: relation, mobilization and knowledge. First of all, it forms a framework to analyze the current state of relation capacity and secondly, gives an idea of potential improvements in case of absence of number of these functions. Furthermore, the section gave a course and tentative explanations of the dynamics of the processes that might be expected at the field work in SOHAR itself.

Evolution stages

And the final outlook which literature review will provide is the evolution process of the industrial symbiosis. As it has already been outlined in this research industrial symbiosis is regarded as a process. Therefore different stages of development of such process can be distinguished. The research of Chertow and Ehrenfeld (2012) provide a good overlook of the main evolutionary stages of industrial symbiosis.

- 1) **Sprouting.** On this stage tenants in the park are exchanging secondary materials and by-products on random and occasional basis. These processes are not governed by any overarching vision or strategy, but rather driven by the market and other external forces. These can be economic benefits, restrictive legislation and pressure from the nearby communities etc. From managerial perspective, emergence of the early exchanges are driven by new market opportunities and cost reduction benefits. And as long as actors see the advantages of synergetic links, these can be sustained and developed. Generally the actors do not really have an aspiration to grow these exchanges and create an active industrial symbiosis network.
- 2) **Uncovering.** Stage 1 will grow into stage 2 once positive externalities or public goods become as significant as worth taking into account for further expansion and building up network around or including them. Generally these exchanges become “uncovered” and recognized by a third party it can be an authority, community or/ and managerial board. The linkages are changing from being occasional to regular and based on bilateral agreements and contracts. Apart from the economic advantage also the environmental benefit is recognized and taken into account in the decision making process. At this stage the role of coordinators, orchestrators and champions is of ultimate importance for further embeddedness and up-take of industrial symbiosis. Favorable intuitional context so as physical infrastructure should arise and start to grow to foster the development of linkages.
- 3) **Embeddedness and institutionalization.** This stage is a natural product of evolvment and strengthening of the processes on the previous stage. Industrial symbiosis becomes intentionally driven, governed by mature vision and deeply embedded into institutional context. The main difference of the stage from the others is the high degree of evolution of the institutional frame around the symbiotic exchanges. The majority of roles defined above is continuously performed and increase in their complexity. More and more synergetic opportunities are pursued creating a sophisticated and resilient network. Chertow and Ehrenfeld also point out increasing significance of the social dimension, more specifically a social capital and tangible benefits reviled for the public.

3 Methodology

For the purpose of this research such research design as case study is believed to serve the best way. This section is dedicated to the description of the process of the research and the methods with the instruments, which are going to be applied.

The overall motivation of this research can be described as evaluation of the current state of the institutional capacity and the context which is shaping in the particular case of SOHAR. And according to Yin (2009) this is one of the four possible motivations why researcher should choose case study among other research methods. To make it clear case-study is “an in-depth study of a phenomenon, such as an event, individual, group of people or institution, within its real-life context and is one of few research methods that investigate both the phenomenon at hand, as well as the influence of the context in which it is situated” (Yin, 2009).

Another supporting argument for the case study is the overall aim at deriving in-depth understanding of the influence of institutional capacity on advancement of industrial symbiosis in the real-world context such as SOHAR Port & Freezone. More specifically, role of such dimensions of institutional capacity as relation, knowledge and mobilization for maturity of industrial symbiosis will be closely examined. Apart from that what is characteristic for the case study the research the case of SOHAR is not going to be studied in the isolation from the external forces. It will include investigation of the institutional context and conditions of SOHAR, which is shaping institutional capacity and have an impact on industrial symbiosis too. As this research method suggests it will focus on important events, adopted practices and embedded approaches, which is also an inherited part of the a case study as a research method (Yin, 2009).

However, this chosen research method has its own constrains. First of all, the conclusion will be based upon the qualitative data, which is not as robust as the quantitative data (Yin, 2009). As pointed out in the literature case study is not capable of encompassing as many variables as in real-life, meaning it has limited power to reflect the reality to 100% (Yin, 2009).

There are several alternative research methods that could be chosen for the purposes of this research. Firstly, it could be grounded theory research. This research is a study of the concept, which could be institutional capacity or industrial symbiosis. On the contrary to case study it does not have descriptive or explanatory nature. The research would focus on a pattern that could be further generalized and explain the reality (Glaser, 2009). Secondly, it could be a developed methodology presented by Boons and the colleagues (2014) called event sequence analysis. In the core of this methodology lies the process perspective and array of actions and events that are leading to the building up the institutional capacity (Boons et al., 2014). To give an example the events that are regarded are orientation, planning and implementation activities, feasibility studies, establishment of strategic vision and so on (Boons et al., 2014). Even though this method can be really helpful to trace development of the institutional capacity the other methodology based upon analysis of the certain indicators was chosen. This method is applied in the range of researches dedicated to IS (Zhang et al., 2009, Boons and Spekkink, 2012).

Case study design

The current research has a clear focus on the industrial park SOHAR Port & Freezone, situated in the sultanate of Oman 250 km away from its capital. The research design can be characterized as an embedded multiple-case study as described by Yin (2009). The reason for is that there are two primary levels of study: on one level it is industrial park followed by multiple tenants of the park, which are going to be interviewed too. And on top of that institutional context will be investigated as stated above.

The guiding theory of the research is the concept of institutional capacity. This concept is initially built up on three major blocks such as knowledge, relation and mobilization capacity (Healey et al., 2003, Boons and Spekknik, 2012). Institutional capacity manages to encompass the main forces influencing the ability of the involved actors to solve common issues and find the compromise among different involved interests (Healey et al., 2003, Boons and Spekknik, 2012). As a result it helps industrial symbiosis to evolve. Therefore, mature institutional capacity is a prerequisite for industrial symbiosis to thrive. Apart from application of the described guiding theory there will other theoretical concepts used in the course of the research. Among them are enabling roles for the development of industrial symbiosis. The research will try to identify presence of so-called champion, brokers, scavengers and decomposers and so on. One of the major shortcomings of this theory is that it does not incorporate the technical aspects of the synergies.

Mostly qualitative methods are applied in the course of the research. For the purpose of accessing the institutional capacity and identifying meaningful interventions various data collection methods are applied. As for the stakeholders, semi-structured interviews are carried out with the consequent transcription and analysis. Among the stakeholders that are of interest for the research purposes are the tenants of the industrial park, Ministry of Environment and Climate Affairs, a waste management company, utility providers and industrial estate management. To support the interviews a special guide is formulated based upon the indicators summarized below. The interviews have the following purpose: establishment of the reference state of institutional capacity, identification of the potential directions of synergies and discussion of the exchanges that are founded by similar industries elsewhere. Observation of the stakeholders' interactions and general practices are the inherited part of the research process as well. And finally policy documents and internal reports are analysed too. In order to ensure the robustness of the qualitative data such method as triangulation will be applied. It means that at least three different sources, these were described, are chosen to arrive to a valid conclusion.

The case study components are going to be backed by a thorough literature review. It aims at synthesizing current state of knowledge with regard to the concept of industrial symbiosis; identify potential areas of interventions and possible synergetic exchanges between given heavy industries; provide theoretical frameworks and constructs for further analysis. Reviewed sources include mainly scientific journals, peer reviewed articles, but also industry reports.

Small-scale interventions

Another essential part will be small-scale interventions, which will aim at improving three levels of the institutional capacity: knowledge, relation and implementation. As was stated previously these interventions are the inherent part of the research.

To improve the knowledge capacity a round-table meetings with the key stakeholders of the port is going to be organized. It will allow bringing the stakeholders together and discuss the current strengths and challenges of SOHAR institutional capacity. Moreover certain identified opportunities for future synergies will be presented to inspire the actors to collaborate. It will be done after the reference state of the park will be explored. Therefore, the round-table meeting will also include recommendation how to improve current institutional capacity and develop the synergies. Preceding to that the concept of industrial symbiosis is going to be presented along with its key benefits and identified opportunities. It also aims at sparking the interest among the stakeholders in developing synergetic exchanges and improve the interaction. Which mean the round-table will also serve the improvement of the relation capacity.

The actors of SOHAR can also find a value in the identified synergies that can be potentially established in the industrial park. That would be possible to do based on interviews with the tenants, internal documents, gathered inventories from the tenants. Moreover, existing cases of IS found in the literature with the similar involved industries also helped to get an idea about the potential synergies that could be established in SOHAR. In the end it will be represented on the map: the current stage, available hot spots and potential synergies.

And finally, the research is expected to result in improvement of the mobilization capacity. The synergetic opportunities and unrevealed areas of interest are going to be described.

Indicators

One the challenge of conducting the qualitative analysis is the operationalization of seemingly intangible concept of institutional capacity. However, it is really important to overcome this challenge since it is overarching concept for the research. By consulting the literature it was possible to get the inspiration for the possible indicators of the institutional capacity. The analysis of these indicators will help to build a certain picture of the current state of institutional capacity. Some indicators will be accessed based on their presence along with their quality and effectiveness. Some of them will be judged as “low” or “high” depending on the findings and facts that are supporting this judgment. Such method as data triangulation will be used to draw a conclusion about the quality of the certain indicators. The indicators are grouped according to the main pillars of the steering theoretical framework in three main groups: knowledge, relation, mobilization. As for indicators for the knowledge capacity another evaluation method will be choosed. Since the main focus for this category is the tenants of the park, indicator for each and every interviewed tenant will be accessed. Then based on the results from all the tenants the final conclusion will be drawn based on prevailing majority.

Knowledge capacity

- the number of carried out technical and organizational feasibility studies;
- the knowledge of stakeholders (decision-makers) about the residual products produced in the park both their own and other tenants
- accessibility of information (companies' reports)
- available mapping with the hot spots and other things
- presence of the analysis mechanism of the materials and by-product flows
- presence and the quality of the accounting mechanism for economic, environmental and potentially social benefits of the existing exchanges

- effectiveness of evaluation mechanism to identify and evaluate potential symbiotic exchanges
- input from the universities with R&D and stimulation of business activities in the incubators

Relation capacity

- availability of the commonly accepted vision, developed master plan and other formally documented intentions;
- intensity of interactions about the common problems and possible solutions
- presence of an integral platform for interaction for the tenants
- effectiveness of collaboration with the nearby universities of R&D
- presence of the (potential) steering body / appointed employee to coordinate IS
- occurrence of the social learning process
- degree of the divergence of interests of the involved stakeholders
- commitment of stakeholders to sustainable development
- support of the government in development of synergies, support sustainable strategies

Mobilization capacity

- the amount of resources that were clearly dedicated to develop synergetic techno-system
- developed waste management system in the park
- access to available funding to support any exchanges
- presence of the recruitment process to accommodate new tenants in the park
- level of participation of actors important for developing the synergies
- diversity of types of the by-products involved in the exchanges and implemented synergies
- establishment and degree of reuse of waste, water and waste gas / heat
- presence of public-private partnerships

4 Findings

Introduction of the main actors

To facilitate readers' understanding of the following section it is important to introduce the main stakeholders of the studied case:

Table 2. The key actors of SOHAR

SOHAR PORT & FREEZONE¹	A deep-sea Port and adherent industrial park situated in Sohar (Oman). 50:50 joint venture between the Port of Rotterdam (the Netherlands) and Omani government.
SUR	Sohar Industrial Port Company. It is industrial estate authority, who owns the plots of land and manages the whole industrial park. It is responsible for recruitment of tenants, provision of all needed infrastructure. On top of that, SUR is gaining partial autonomy from the Ministry of Environment and Climate Affairs when it comes to the environmental permitting and air quality control within the industrial zone. Therefore, together with the park's tenants it carries out its own environmental management program.
TIWI	governmentally owned waste management company, appointed by a Royal Decree to be responsible for the solid waste management in the whole country. Monopolist on the market in a way that it has to give approval for any other waste company to operate within the certain area for the certain client. Without consent from TIWI neither a company can arrange the contract with a waste operator, nor the waste management company to enter the market.
MECA	Ministry of Environment and Climate Affairs, overlooking authority managing environmental affairs in Oman.
AL QABIL	Oman Oil Refineries and Petroleum Industries Company, an anchor tenant in the industrial park

4.1 Description of the SOHAR Port & Freezone

The object of this study is Sohar Port & Freezone., which is situated in the second most populated region in the sultanate of Oman, 250 km from the capital city of Muscat. The development of this region that called Al Batinah is directly connected to the development of Sohar Port. In fact, it is a part of a Special Economic Zone, which encompasses several key infrastructural developments: SOHAR Port and Freezone, Sohar industrial estate, Sohar airport, rail terminal and Port of Shinas. The special economic zone is designed in the integrated manner to make the best out of common infrastructure and neighboring industries.

In terms of significance of the port zone itself Sohar is one of the major ports and industrial complex in Oman competing with the biggest port in the Middle East Jebel Ali located 300 km away in Dubai (The Economist, 2015, Container News, 2016, Oxford Business Group, 2017). Sohar Port has very a strategic location being situated in the middle of the global trade routes between Asia and Europe. Sohar Port handles over 50 mln tons of cargo. To put it into perspective the largest port of Scandinavia the Port of Gothenburg handles 40 mln tons of cargo (Portofgothenburg, 2017). However, the largest European Port of Rotterdam handles 461.2 mln tons, including dry, liquid, container and breakbulk (Portofrotterdam, 2016). Sohar Port & Freezone hosts four major clusters

¹ All the names of the companies have been changed to the figurative names of Omani cities and towns due to confidential nature of this report.

such as logistics, petrochemicals, metals and energy, which can be seen on the picture below (Figure 6).

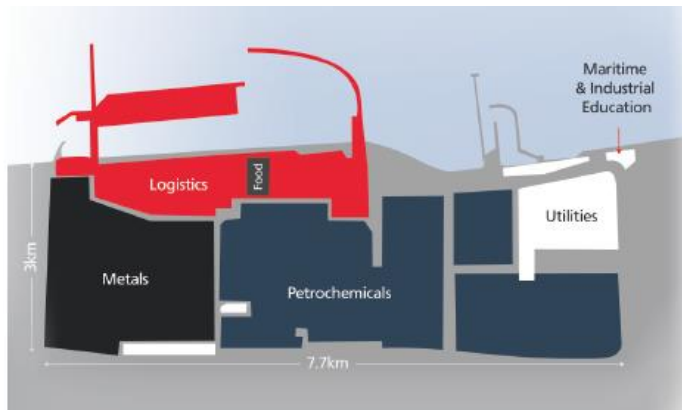


Figure 6. The set up of the industrial park

Overview of the clusters

It is worth noting that the clusters are situated in the two main zones that in total comprise SOHAR industrial park. These are the Port zone and Freezone placed a couple of kilometers away from each other. It is worth noticing that the Port zone has its name due to proximity to the zone, where the marine vessels are operating. However, in Port Zone in this context is solely industrial area, which has nothing to do with the marine operations. As it can be seen on the picture the coverage of the Port zone is 7.7 km by 3 km. This zone is complete in terms of available plots of land for new tenants; however a number of new developments are still in progress. When it comes to Freezone then this part of the park is not as accommodated as the Port zone leaving a lot of available territory for the new industries. Total available territory equals to 3500ha, but total occupied surface with industries currently equals up to 900ha (Masterplan, 2017).

Looking closely at the Port zone one can see three main clusters mentioned above. The most notable one is a **petrochemical** one. The main anchor here is AL QABIL oil refinery processing 116,000 barrels per day. The cluster consists of six plants, which all together comprise an integrated chain of the oil refinery process: an oil refinery, polypropylene (340,000 MTPA) and aromatics plant (1.01 BTPA), fertilizer factory, methanol production and formaldehyde company (Al Jabri, 2016). The chain represents different stages of oil processing process a number of links in terms of supply of feed-in stock is already established, which clearly represents supply synergies. To complete a value chain from oil to the finished products polymer factories are planned to be accommodated in vicinity of the oil refinery plant.

The next cluster is the **metal** one, which constituted of 3 steel plants and situated in the Port Zone. Moreover there are 2 ferro chrome manufacturers and a metal recovery plant that are located in Freezone. The linkage has been established between an iron ore pelletizing company AL BUSTAN and an integrated steel plant. AL BUSTAN has two production lines with the total capacity of 9 MTPA and delivers iron pellets to YITI (Al Jabri, 2016). In its turn, YITI has the capacity of 1.4 MTPA for production of iron (Al Jabri, 2016). Further down the value chain LINAH and SINAW Steel (0.25 MTPA) receives scrap and other by-products from YITI and perform metal recovery services. LINAH recovers iron from the steel slag generated from YITI plant in the Freezone and SINAW Steel from in the Port zone.

And finally the **utility or energy** cluster, which encompasses six tenants. It includes a combined power and water plant, another two power suppliers and a gas supplier. Next to it there is electricity

and water distribution authority and water Service Company, which supplies cooling, process and potable water for the whole park.

4.2 Issue of scoping industrial symbiosis

Before starting the field work in SOHAR industrial park the company provided a lot of documents to get familiarize with the park, clusters, and tenants etc. One of the documents prepared prior to the research was “Feed and Finished product map” of the metal and petrochemical cluster. From the first sight, it can be seen that some synergies have already been present in the park. And to the certain extent integration in the park is present. Certain products and streams are being exchanged in the park. However, under closer look one can see that among these products are crude oil, natural gas, and methanol and so on. For instance, in upper right corner it can be seen that from AL HADD and AL HAJAR go such streams as urea (chemical) and methanol (figure 7). These products that do have commercial value and are exchanged based upon normal commercial terms. Therefore, there was confusion from research point of view: How regular commercial transactions can be distinguished from industrial symbiosis arrangements? What does industrial symbiosis encompass and what has to be left outside its scope?

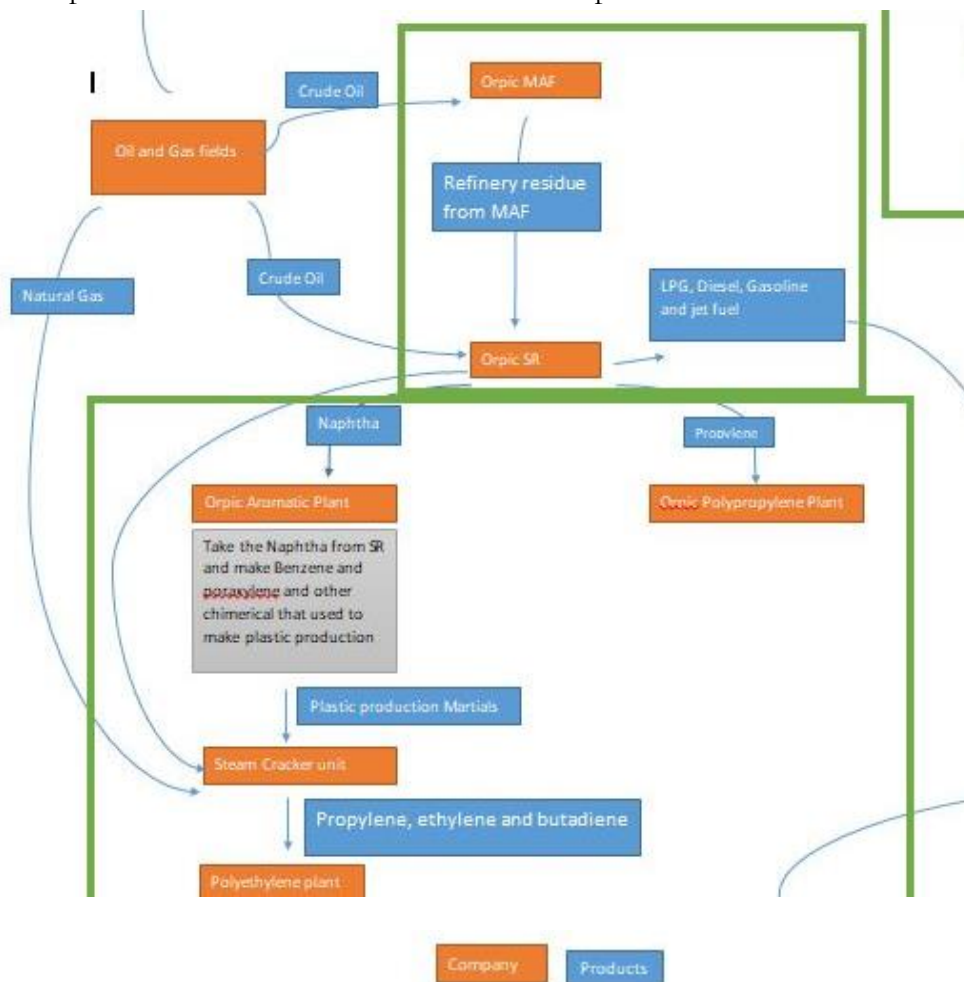


Figure 7. The map of supply synergies in the park

In order to answer this question first of all numerous definitions have been revisited. In the one of the works of Van Beers (2007) the author also excludes this type of exchanges motivating it by stating that “they do not meet the criterion of resource exchange between traditionally separated industries as distinctive feature of industrial symbiosis”. Apart from it, industrial symbiosis is generally concerned about the by-products and streams that otherwise would be discarded (Deutz,

2014, Hein et al., 2016). After consulting the literature it also became clear that two types of exchanges would be left outside the scope according to Branson (2013). First of all, these are products that are produced with the purpose of realization on the market regardless where it is. Secondly, these are the synergies that are based on the exchange of products for the core business of the actors (Branson, 2013). And one of the most remarkable features is that the industrial symbiosis exchanges are performed on highly specific terms and maybe even unique to a particular context and agreement (Branson, 2013). Therefore, a new map of the existing synergies was created (figure 9).

In fact, this “scoping exercise” has already been performed by AL QABIL. A lot of by-products from the oil refinery are not categorized as “waste” within the factory, because it has very distinct market value and therefore sent to the other users (Al Saidi, personal communication, 2017). Thus, the market has defined either it is a product or “waste”: if it does not leave the gate of the company or go to the landfill then it can be called waste, materials which are going to the market and provide additional revenue streams - product. In fact, it is a common practice that secondary materials from an oil refinery are meant for the further processing in a number of industries, which in our case fall under category of supply synergies. This real-life example showed pretty much the same logic, which has been applied to define scope of existing exchanges.

REFERENCE STATE

In order to answer the research questions and give meaningful recommendations on how to improve current institutional capacity it is important to establish the reference state of the context. Therefore, in this chapter the following findings: barriers and drivers for development of IS in SOHAR context, identified enabling roles for IS, description of the three building blocks of the institutional capacity and finally present existing synergies in the park.

4.3 Identified drivers for the synergies

During the field research some synergies has been identified. It is important to understand the drivers for already existing exchanges to be able to judge the potential of other options. Among the main drivers the following points can be brought up:

- cost of the waste disposal
- congested tenants' premises
- economic benefit
- reliance on the fossil fuels

There is a clear absence of the mechanisms applied by the government to push industries for smart usage of energy and resources. However, it is only temporary and the pressure might start to increase in coming two years (Halls, personal communication, 2017). But what is really of concern for the companies are, first of all, upcoming costs of waste disposal that are imposed by TIWI. The company is actively developing waste disposal options, physical and chemical treatment of waste and along with that the tariff system. To give an example, initially projected costs for the most problematic waste stream such as slag was 7 OMR (Omani rial) per ton (€14), which after negotiations between TIWI and SUR is drive down to 1 OMR per ton (€2) with the future increase. That perceived to be unreasonably high both for the tenants and industrial estate authority taking

into account the scale of slag issue. Therefore, the companies have mobilized their resources to find alternative solutions either inside or outside the park.

The second issue that often came up during the interviews is congestion of the tenants' premises. Initially companies started to operate without paying much attention to their waste problem. The space of disposal and storage seemed to be abundant. However several years down the line generated volume of waste started getting relatively high. The companies were faced with the necessity to expand their storage facilities for the hazardous and other types of waste (De Jager, Nissen, personal communication, 2017). And it is very costly for the company to build a new hazardous waste storage site. Moreover, as was mentioned during the interview with MECA a lot of companies are not allowed to store their waste more than several months according to the issued permits (Al Shihi, personal communication, 2017). However, the practice shows that the waste has been stored for years. But the government currently "closes its eyes" on the issue due to unavailability of the feasible option for the industries. Perhaps the most severe issue is literally the mountains of accumulated slag. The tenants themselves commented on that as: "I simply do not have space anymore!!" (Sahoo, personal communication, 2017). Therefore, any option for the reduction of accumulated waste is very welcome in the park.

And final point is a strong economic drive. As long as a certain synergy can deliver a cost reduction for the tenant it would be of interest to consider it. There are a number of such examples in SOHAR. For instance, YITI was looking for the opportunities to reduce their electricity consumption since they have in operation an Electric Arc Furnace. Any material with high carbon content would be of interest, which has been communicated during the monthly gatherings of HSE and Environmental specialist. The first company that got back to YITI was Sohar Aluminum, which was suffering from the accumulation of refractory waste. After a series of trials the material was approved, contractual agreements formalized and the synergy established. Thus, the waste accumulation for one company is solved and at the same time significant cost reduction for another is achieved (Singh, Al-Muqbal, Al Reesi, personal communication, 2017). In fact, support of YITI driven by the economic interest helped Sohar Aluminum to obtain the initial permit for trial much easier. There are some other examples of this sort are present in SOHAR.

And finally it has to be mentioned among the drivers for IS is realization among the top management of industrial estate authority the risk of reliance on the fossil fuels. Natural gas is largely dominating in the energy mix of the park and so far only plans are discussed for its diversification. Having core a responsibility for providing a source of energy for the tenants, rapid increase of the fuel in price or shortage of supply pose a great risk for the industrial estate authority. Therefore, it is in its interest to facilitate energy-efficiency, application of renewable energy sources as solar and recovery of the waste heat.

4.4 Identified challenges

Regulatory

Quite significant number of regulatory barriers has been identified, which can be shortly summarized as the absence of incentives for the industries to apply circular thinking and support the synergies.

The challenge that comes up perhaps the most is absence of support of re-use and recycling initiatives by Ministry of Environment and Climate Affairs. First of all, in order to carry out one or

another project the approval from this ministry should be acquired. In a lot of cases, the challenge is the lack of expertise within the certain area, which results either with the major delay or the rejection of the project.

One of the multiple experiences on this matter could be given with the most urgent problem of slag re-use. One of the fertilizing company (Al-Batinah International S.A.O.C.) has approached SINAW Steel in order to purchase the slag from them and use it for the production of their natural fertilizers. Therefore, it would be a good opportunity for both parties to utilize the slag. For the initial stage the company would like to acquire some slag to test it for their product. However without the approval from MECA it is impossible to proceed. The permission is being awaited for a couple of months up until now. Yet it is relatively short period of time, because Sohar Aluminum was waiting for the permit for the trial purposes for 2 years before it could proceed with cooperation with YITI. To put it into perspective Salmi (2011) informs the readers that it took a steelmaking plant in Sweden six years to remove the status of waste from generated slag and metal scrap. Despite the fact that Sweden is famous for its proactive approach to waste.

What is also important to mention is that some of the generated by-products in the park cannot find the application within Oman due to underdevelopment of the certain industries. Yet the theoretical possibility could be to export the waste outside of Oman, where it can find the market and already existent application. In this case the Basel Convention applies, which prohibits any trans boundary movement of waste unless it is intended for recycling and re-use (The Basel Convention, 1992). A principal mechanism of the Basel Convention is obtaining a consent letter from the country of import. According to tenants this required consent letter that a receiving party is agreed to accept the waste is not an issue to obtain. What is difficult is to get permission from TIWI for waste to leave the country (Singh, Mohd, personal communication, 2017). In fact, a signatory country of the Convention should nominate a competent authority, which is administrating these types of inquiries. In case of Oman it handles by TIWI, which in its turn is protecting its mandate for the national waste market.

Continuing on the previous point, the reason why by-products cannot find an alternative application within Oman is the absence of the standards for re-use and recycling. That makes industries being reluctant to deviate from their usual practices and innovate reducing the environmental impact of their operations.

One of the examples within SOHAR industrial park also resonates with the regulatory barrier described in the literature. It refers to strict transportation procedures and requirements in case of dealing with material classified as “waste” (Van Beer et al., 2007). Having read about the synergy between Statoil oil refinery and fertilizing company (CECP, 2007), AL QABIL was inquired about the possibility to transfer liquid sulphur to AL HADD, local fertilizing plant. The reason for non-existence of this synergy was mentioned strict regulation from MECA of the transport of such hazardous material on the roads in the liquid state (Al Reesi, personal communication, 2017).

Furthermore, there is a regulatory shortcoming of the enforcement system. On top of the fact that it takes a long time to obtain the permit, which can take up to three year for the major project, there is a high possibility that nobody is going to check and follow up on the compliance (De Jager, Ambusaidi, personal communication, 2017). As for the time issue MECA itself explains that before a project gets its permit, it has to go through a lot of departments specializing on different issues,

such as air quality, soil and water pollution and so on. That was mentioned to be a reason for the delay. Therefore, there is no continuous pressure on the industries from the authorities to comply with the regulation and keep carrying out declared environmental policy. So basically it is quite often a case that companies receive their permits environmental agenda becomes something secondary on the agenda (De Jager, Ambusaidi, personal communication, 2017). Next to that there is no elaborated system of fines for non-compliance, which could stimulate the companies to take care of their environmental impact on the constant base.

Another big issue in the park is strong authority of the TIWI. Any initiative concerning waste has to involve TIWI either directly or indirectly by obtaining “non-objection note” from it. However, the challenge is that first of all, in many instances the company does not have enough expertise to support the company’s intention to find alternative application of waste (De Jager, Ambusaidi, Halls, Lobo, Hussein, personal communication, 2017). Therefore, it does not give a green light to the project or it takes very long time. The example with the SINAW Steel can support this argument. As it was mentioned during the interview the company has limited choice of recyclers to make use of their solid waste. The company was not free to choose any recycler, but TIWI sent one of their agents that in their opinion was credible. However, the agent refused to take care of the waste due to low quantity of waste. SINAW Steel continued the search and finally recently found a waste operator.

And finally there is a certain arrangement in the park, which can be left without attention. In case of Oman, industrial estate authority is given to certain degree autonomy from MECA. The model where an industrial estate authority has partial autonomy from the environmental ministry is different from the European practices, where an industrial authority has to comply with the wide range of the governmental regulations. MECA let SUR to take over the functions of air monitoring, drafting environmental conditions for permits and in certain cases also issue them. On one hand, the autonomy could lead to the adverse consequences and downgrading of applied environmental standards. It is especially dangerous in the country, where sound environmental management is in its infancy as in Oman. However the balancing mechanism in this situation plays one of the two shareholders, which is the Port of Rotterdam. In this way no major projects could be approved without the Port of Rotterdam, which that has very high standards for all the operations. What became a common practice here for SOHAR in case Oman does not have a certain standard in place for a project a strict Dutch standard would be applied. In its turn the Dutch approach to the environmental issues is really pro-active.

Economic

Perhaps the most apparent economic barrier that is impeding development of Industrial Symbiosis is cheap fossil fuel, which is in case of the park is mainly gas. The majority of companies have chosen Oman due attractive gas price and its abundance (De Jager, Halls, personal communication, 2017). Therefore as long as the prices remain low, there will be no push for the companies seriously consider energy saving measures. Another aspect that is coming into play is absence of market-based mechanism incentivizing companies to look into energy and resources efficiency. On the contrary, for instance, to the tenants of the Port of Rotterdam or Kalunborg Park, where high prices of energy and taxes made companies to look for the energy related synergies.

Also due to the fall in fossil fuel prices budgets for the research institutions were cut. Previously high prices of the fossil fuels motivated research on Industrial ecology and energy-efficiency. However now the interest from the private sector has vanished due to unattractively low prices for the investments in the energy saving projects. However, high revenues for oil and gas were significant income for the state budget that allowed launching at the time the program for the cleaner production (Halls, personal communication, 2017). However, due to lack of current funding this initiative is put on hold.

Institutional

What has been discovered during the research is significantly low capacity of MECA in terms of knowledge and expertise. A lot of employees do not have the right background, which result in low awareness and low perceptiveness of the challenges and opportunities on the ground (Halls, De Jager, personal communication, 2017). During the interview with the MECA representative it was mentioned that all six people, who dealing with the waste issues, have chemical background. However, the waste issue is complex incorporating technical, social, regulatory and environmental aspects. Therefore, the department would significantly benefit from the diversity of expertise and background of employees. What is the most alarming that it is the more of the case for higher decision-making level, where most employees do not have environmental background (Halls, De Jager, personal communication, 2017). That also leads to inertia with decision making and adoption of new policies within the Ministry (Halls, personal communication, 2017). Perhaps another consequence is the fact that sometimes it takes a long time before the important message reaches and perceived in a right way by the decision makers. It has to be repeated multiple times (Halls, personal communication, 2017).

The Ministry also has pretty limited experience with the case of re-use and recycle initiated by the industries in Oman (Halls, De Jager, Al Shihi, personal communication, 2017). That makes each individual case to be considered by authorities for a long time and rather sceptically. What also play a major role in that respect is the common perception within the Ministry of “waste” as “residues” and not a “by-product with potential value” (Halls, De Jager, Al Shihi, personal communication, 2017). During the interview with MECA the representative of the ministry has acknowledged this prevailing perception. That is a clear hindering force for the synergies.

Furthermore, when it comes to the decision making TIWI is the main advisor for the Ministry. Partially this arrangement is also due to the lack of expertise within the Ministry as already mentioned. As the interview with TIWI representatives has identified that development of re-use and recycling field is not currently of high priority for TIWI (Nissen, personal communication, 2017). On the contrary, the company’s current strategy is to provide such services as collection, disposal and landfilling (Nissen, Ambusaidi, De Jager, personal communication, 2017). The most ambitious project is to build the incineration facility for the hazardous and municipal waste, which is far away from 3R approach (recycle, reusing, reduce) (Nissen, Ambusaidi, De Jager, personal communication, 2017). The resources of the company are distributed accordingly (Nissen, AL Shihi, personal communication, 2017).

Organizational

There are a number of organizational barriers, which has been noticed in the park. What has been discovered during the interviews is that quite often the barrier for the cooperation is absence of experience of the recipient companies to accept by-products and waste in their operations. Lack of knowledge and experience makes the risk for companies seems to be higher than it might actually be. An example of this is negotiations between oil refinery and the cement company to accept spent catalysts. And another case is the attempts of AL BUSTAN to set up the collaboration with Oman Portuguese Cement company to take their refractory waste. In both instances the reason for rejection was risk averse policy of the recipient and unwillingness to go deal with official red tape from MECA.

Another organization barrier that has been identified is the tendency among the tenants to have one operator for all types of waste. This operator should be approved by TIWI. It helps to save time and paper work to deal with the multiple streams and thereby divert the attention from the core operations (Mohd, personal communication, 2017). However, that deprives the opportunity of the tenants to use some materials within the park for the benefit of the other company. One more observation provides the evidence that the companies tend to rely more on waste operators rather than trying to find the application among the neighbours.

In addition, an interesting for further analysis situation took place in the park. Sohar International Urea & Chemical Industries (AL HADD) the company needs to have extra CO² supplied for its operations. The first step was to see if this need could be satisfied internally. So the company explored the opportunity to recover CO² from the exhaust gases. The next preferred option was to ask the neighbouring industry about the availability of the excessive CO². However a seemingly promising initiative was put on indefinite hold. The reason for this refers to technical barrier, because the oil refinery would need CO² itself for the future expansion project, which is in the pipeline. As the result AL HADD could not get the needed resource from the tenant next door. However, no attempts were further undertaken to approach other companies even though it would be very beneficial for AL HADD's operations. Tentative reason for this is explained in the analysis section.

The following case encompasses illustration of different types of barriers. However, among others is an organizational one, which is lack of experience of companies to deal with the by-products as a feed stock. It goes about hardships of AL QABIL and AL BUSTAN (iron company) to find an environmentally friendly applications for their refractory waste. That waste is used in the lining of the kilns and a lot of times consist of the fire clay, which basically reminds of bricks. Since this material is non-hazardous it can be successfully applied in the construction industry. The attempts were undertaken to cooperate with Oman Portuguese Cement Products situated in close proximity. Even though the cement company saw the value in the material and it would really substitute their feed-in stock, they did not want to take a risk and have time-consuming process of obtaining the permit from MECA. That serves in indication for a regulatory barrier. AL BUSTAN itself commented it as a problem of trust. Eventually, Oman Portuguese Cement Products stuck to the business as usual and the cooperation failed to exist. However, the research showed that there are two companies in the park, who could supply the same material to Oman Portuguese Cement Products.

And finally during the discussion with the power company about the possibility to use the excessive gas coming from the oil refinery surfaced another organization barrier. It was mentioned that it

might breach the existing contractual agreements with the existing supplier, which is in hands of senior management to handle.

The issue of the business models

As pointed out in the literature review, one of the enabling mechanisms for synergies to evolve is efficiently applied innovative business models. A couple of noted instances give an indication that there is a potential problem on this front.

Governmentally owned water company called QURM is mainly supplying three types of water: cooling, process and potable. Used technology for the water purification purposes is reverse osmosis, which is commonly used for water desalination. However another way to desalinate the water is evaporation utilizing waste heat. This approach is used by a number of companies in the park, including all the companies in petrochemical cluster. These kinds of practices are posing a danger for the core business of QURM. If a company or a number of companies jointly can satisfy their own needs for processing water then QURM is out business. To add to that QURM invested in the pipeline infrastructure, that is why it cannot afford infrastructure under capacity. In case companies will try to cooperate and arrange their own desalination plant, QURM is going to oppose it since it is jeopardizing their business. The way QURM secured its position by establishing 20 - years contractual agreements with the tenants, which, from their point of you, are not flexible enough to lower the supply (Al Saidi, personal communication, 2017). Moreover, it was mentioned that the company would inquiry losses in case it does not use the infrastructure provided by QURM. During the interview it was mentioned that the tenants which are applying for the permits to build their own desalination plant in the park are facing very lengthy and complicated procedure. The reason behind it could be a will of authorities to put QURM forward since it is the governmental company (Al Saidi, personal communication, 2017).

Talking about the trouble for SINAW Steel to find the waste management company also reveals issue of business models. The role of the TIWI Business development department is to support the request coming from their clients such as companies within the park. However communication with such tenants as AL BUSTAN and Sohar Stell showed that TIWI did not perform the role as diligently as expected and the companies had to find the operator themselves (Mohd, Hussein, personal communication, 2017). It is normal practice in Europe though, where polluters are responsible for finding a waste operator. However, TIWI has better overview and experience with the waste operators in Oman. According to Bocken and his colleagues (2014) TIWI could have followed such strategies as maximization of material and energy efficiency; createion value from waste and most importantly adopt a stewardship role to find the most efficient itilization and disposal method for tenants are looking for.

And finally the example of Oil Tanking, which is lingering with the investment into dehumidification of its by-products to collaborate with YITI (Singh, personal communication, 2017).

Technical barrier

The nature of the interviews carried out with the stakeholders did not imply deep investigation of the technical possibilities of collaboration between the tenants. However what did came up repeatedly is the fact that factories processes are designed in the closed loop way. To give an example, all the waste heat is entirely utilized either back in the process or for water desalination. Or

in case there is a need in the resource which can come from the outside it is technically challenging to adjust already well-functioning operations.

Another often arising issue is absence of these technologies and practices in Oman, which can treat and process certain types of waste. For instance, AL QABIL and Methanol produce considerable amount of wax that can be turned into a product. To add to that AL BUSTAN is importing cellulose pellets all the way from the Netherlands to avoid dispersion of dust from the storage area (Hussein, personal communication, 2017). The basis for this product is pulp, which is present in Oman. But there is no technology to turn it into this kind of product that AL BUSTAN requires. And finally, there is absence in Oman of the technical possibility to send spent catalysts for regeneration.

Information barrier

Quite a serious knowledge gap was noticed during the interviews with the tenants. Almost none of the companies are aware of the inventories of the neighbours and have no idea whether there might be something of value for them out in the park. Apart from that there is simple lack of knowledge that some synergy could be technically carried out and be mutually beneficial. For instance, to tackle the problem of accumulation of ferro-chrome slag on the site the multiple researches show possible application in the foundry industry. The representative of these industries that is situated in the park is Sohar Aluminum. However neither of tenants is aware of this technical possibility. Furthermore, what has been already mention multiple times is lack of knowledge in the governmental structures especially within the Ministry of Environment and Climate Affairs, which could play a leading role in promotion of innovations and industrial synergies.

Another important aspect is the involvement of academia in overcoming informational gap. For instance two prominent Australian cases Kwinana (Western Australia) and Gladstone (Queensland) rely a lot on the assistance from researches for the identification and development of new synergies (Van Beers et al., 2007). And the collaboration between academia and the industries is developed really well and results in economic and environmental benefits for the region (Van Beers et al., 2007). And as of now the first major case would be realized providing the evidence of the involvement of academia, which is research about alternative application of slag.

5 Analysis

Current state of the institutional capacity

In this section the findings specifically about the current state of the institutional capacity will be presented. The information is divided into three sections according to the literature reviewed in: relation, knowledge and mobilization. For the better visual representation of the assessment of the each state of the block, the findings were summarized in the tables. Each table consists of the indicators described in the methodology section.

5.1 Current state of relation capacity

Table 3. Evaluation table of relation capacity

RELATION CAPACITY	
R1 Common vision, formalized intentions	✓
R2 Intensity of the interaction within the park with clear intention to cooperate	HIGH
R3 Platform for interaction	✓
R4 Effectiveness of cooperation with the universities	LOW
R5 Appointed steering body / employee	✗
R6 Learning process	✓
R7 Degree of divergence of interests	HIGH
R8 Commitment to the sustainable development	✗
R9 Support of the government	✗

R1. Common vision and formalized intentions

The importance of the developed vision has been outlined in the literature review section. There is recently developed document, which clearly outlines the intention of SOHAR authorities to implement industrial symbiosis - "SOHAR Port and Freezone Vision and Master plan 2040". It was developed jointly by the Dutch and Omani decision makers and counterparts. Commitment to industrial symbiosis can be traced in plans of expansion and further development of the park. Consultancies helped to identify among key success factors for future business.

The Vision and Masterplan which are combined in one document are built up upon Masterplan for Al Batinah Region prepared by The Higher Council of Planning. On the broader level, SOHAR is one the piece of the puzzle in the development plan of Al Batinah Region.

The plan consists of the airport, future railway, industrial estate, the sea port and the Freezone itself. Zooming in to the planning of the industrial zone itself Masterplan says that SOHAR Port & Freezone is inherently "planned in an integrated manner, bringing benefits in terms of ... increased synergies between developments".

As for the future prospects in the spatial development plan it is mentioned that some new areas are going to be developed and the new clusters established. Among them is a food cluster that offers a lot of synergetic opportunities, which is going to be touched upon later. Moreover, the Masterplan notes that there is an "opportunity to reinforce the petrochemical cluster by linking the industries". Ideas for the potential tenants, which can bring added value to the park, are also mentioned in the document. For instance, bio-fuel petrochemical plants and a tank terminal are suggested. Accommodation of new bulk activities in vicinity of present petrochemical plants is believed to minimize the externalities caused by current tenants.

To realize SOHAR 2040 Vision seven success factors have been identified. What is of interest for the research is that "innovation climate" was recognized a critical element among other. From point of view of the Port, SOHAR "needs to be innovation-ready to be able to attract innovative concepts

and companies with world-class operations that are early adopters of innovation” (Master plan, 2017). Referring to the literature mentioning of among “potential new economic activities” of energy-efficiency serves as another indicator for emerging of IS (CECP, 2007). Proclaimed way to achieve is “more integration of industries (steam, waste heat, CO² etc)” (Master plan, 2017).

And perhaps the most obvious commitment for industrial symbiosis is: “continuous improvement of operations is encouraged, and companies in SOHAR cooperate to create synergies”. With the help of consultants the most promising areas for synergies were recognized. These are capturing and re-using heat, CO² and steam, which is confirmed by further findings during the fieldwork (Masterplan, 2017). And finally “cooperation to increase synergies” was named as a feature of an innovative firm, which is something that SOHAR tries to encourage (Masterplan, 2017).

However, due to the fact the vision has just been elaborated no actions are taken yet of communicating this kind of values or engaging other stakeholders: tenants, ministry etc. Therefore the foundation stone is laid and the next step is to formulate the strategy for the implementation of the vision. Therefore, some further recommendation on development of the relation capacity will help to realize the vision.

R2 Intensity of the interaction within the park with clear intention to cooperate

There are some examples of the willingness among the tenants to go beyond their corporate boundaries and look for mutually beneficial solutions and cooperation. However as it will be discussed in frames of the knowledge capacity, there is very limited knowledge about beneficial energy or materials flows of neighbours.

However, one vivid example would be certain degree of collaboration on the slag issue. BARKA, a ferro-chrome company with the most urgent status of the slag issue, in collaboration with SUR play an active role of getting stakeholders on board and address the problem. They are actively involving academia in the efforts of finding scientific proof of re-use of slag and other metal companies in the park. Combined efforts of SUR, BARKA and other companies resulted in on-going negotiation of conducting research on re-use of slag. This research is planned to unite concerned companies in the park, TIWI, MECA and two other Ministries. Participation of the above mentioned stakeholders is crucial, because they are giving the construction companies (intended users for slag) license to operate and to utilize the slag in their production. However, despite of the scope of the problem not all companies agreed to be on board and still lingering, e.g. YITI.

Therefore, combination of the external regulatory pressure and internal problem of the congested premises pushed BARKA took a role of the organizational champion. This organization is the most active organization in addressing the slag issue. BARKA is mobilizing the resources and attracting new stakeholders on board.

Furthermore, this case brings us to conclusion that collective actions are much stronger when it comes to solving major issues. Perhaps would could also help is formation of the metal industry association, whose voice will be more powerful rather than a single organization.

Another example of the tenants approaching each other is search of YITI the source of the carbon as alternative resource for its Electric Arc Furnace. They have approached Sohar Aluminum, which did have the waste product of the interest. Common efforts of both actors resulted in obtained

permit from MECA, however it still took quite awhile - 2 years. The trials were carried out successfully showing good results. Now there is an existing established synergy. Having gained the economic benefits and secured access to relatively inexpensive resource YITI is still interested in new partnership. An attempt was taken to attract new suppliers of the carbon material during the round tables at SUR some time ago. The message YITI delivered is that there was a need in carbon rich material and they were open for collaboration. Despite availability of carbon material at AL BUSTAN, only one company, which is Oil Tanking got back to YITI. The driver for Oil Tanking is the same as for the metal company - high volume of waste accumulation. Even though the partnership was mutually beneficial the negotiations stumbled upon the technical requirements from YITI. For Oil Tanking to comply with these requirements certain treatment of waste material should be made, which requires investment. Over the time negotiations quietened and have not been initiated again. Both actors reckon that the decision now should be made on the senior management level at Oil Tanking to proceed further. Another guess was made by YITI saying that waste handling is not core business of Oil Tanking, so they do not want to put much time and efforts into it. That serves as an indication of unsustainable business models prevailing in the park.

It has to be noted that if the process of knowledge sharing works better in the park, then SINAW Steel should be also involved in this initiative of finding the resource substitution. SINAW Steel has the same Electric Arc Furnace and can be potentially interested in similar to YITI savings and benefits.

Described cases also highlight the importance of the brokerage function. To address unwillingness of the companies to divert the attention from their core business the role of broker can be formalized. The broker can help the company to mediate their interest and operation needs, look for a good match in the park or outside it and finally facilitate the collaboration.

The issue of perception in the park

Analyse the interactions between the tenants in the park brings up an interesting phenomena of “short mental distance” and “commercial and political distance”. Mentioned in the organizational barrier section example of AL HADD and its search of extra CO² is a very vivid illustration of “short mental distance” term introduced by Branson (2015). To remind the reader the representatives of AL HADD approached only AL QABIL in the park, because SIUICI knew business and operations of AL QABIL well enough to approach them. Moreover the companies are situated in close geographical proximity having the plants right next to each other. In this respect the social contact played an important role, but did not give any results. No further attempts are known about approaching other tenants in park even though there is a great need of CO² for SIUICI. The company explains it as: “to our best knowledge there no available CO² that could satisfy our needs” (Murudanandam, personal communication, 2017). Perhaps improved interactions and knowledge capacity, which will be further discussed, can facilitate this process.

Another example refers to the attempts of AL QABIL to find an application for its material such as spent catalysts. One of the alternatives could be to send it to the cement plant, which will use it as a substitution of the resource they are using. In 2-3 hours driving distance from SOHAR park there are at least two major cement companies, one in Muscat 250 km away one in UAE 120 km away. Even though the factory in UEA is closer in comparison to the one in Muscat, UAE does not export any hazardous waste to cross the country border (GovernmentofDubai, 2009). The literature says about this kind of setting, that symbiotic linkages can be inhibited not by the distance per se, but political aspects that are affiliated with the location (Branson, 2013). Even though UEA cement

factory might be a viable option from geographical proximity point of view, but as of now Muscat is the preferred arrangement based on commercial proximity logic.

R3 Platform for the interaction

Industrial Symbiosis requires collaboration and active communication between the parties. Keeping this in mind it is important to establish a platform, where the stakeholders can express their ideas and discuss potential ways of cooperation. In case of SOHAR there are monthly meetings for the representatives of HSE (Health Safety Environment) and environmental departments chaired by SUR. However, often times important environmental issues and topics are not getting required “stage” for discussion. Issues related to health and safety is on top of the agenda. Therefore, even though the meetings are carried out on the constant bases what is missing is the agenda of integration and connectivity in the park.

R4 Cooperation with the university

Conclusion about this indicator is based upon the findings derived from the interviews shown in the table on the mobilization capacity (table 4). As it can be seen in Table 4 almost half of the respondents are in one way or another collaborating with the universities. In case of the metal companies it is mostly about alternative application of slag. In other cases academia is not involved in the researches with agenda of energy and resource efficiency and similar topics. However, as described earlier usually the industrial parks, which have intention to develop synergies, do rely on academia and significantly benefit from it (Van Beers et al., 2007). Therefore, answering the question whether the tenants and SUR sufficiently cooperate with academia, the answer would be negative.

R5 Appointed steering body or employee

Even though developing of an integrated park, where a lot of innovations are taking place, is a course for the development according to Masterplan and Vision, there is nobody formally responsible for that. Neither a steering body nor a specific employee is pushing this agenda further. Partially environmental department within SUR is performing some activities that may eventually lead to integration, however it happens unintentionally. Another function that steering body could be as mentioned to mediate the interest of the tenants to find application of their by-products and facilitate the collaborations.

R6 Learning process

As it was mentioned in the literature review section social learning is an important process that indicates development of IS and capability to solve common problems. One of “the exercise” that the actors in the park are going through, which can be attributed to social learning process, is collective resolvment of the issue with slag. As described in the literature this problem brings actors together and forces to go beyond the corporate boundaries to solve a common problem. Therefore, it can be concluded that to some extent the process of social learning does take place, but it should be facilitated further. This is something that is going to be discussed in the next chapter.

R7 Divergence of the interest

Among the barriers a number of conflicts of interests have been described, these included QURM and water desalination units of the tenants, TIWI’s policy and efforts of the companies to divert the waste from the landfills. What can address the issue is adoption of innovative business models. The schemes should take into account new ways of value proposition, value creation and its capturing.

Another concern of SUR about the reliance on the fossil fuels and the opinion of the tenants that prices of gas are cheap and supply are indefinite. Here the implementation of the recently adopted vision will be of help. SUR should communicate and create the understanding about the vision of increasing the share of renewables, looking into CO² capturing and waste heat recovery. Apart from communication also SUR should try to mobilize resources to move towards the achieving the vision.

R8 Commitment to sustainable development

Here the context of the case should be taken into account: heavy industries which made a choice to place their production and manufacturing at the location with very cheap access to fossil fuels. Therefore, after several attempt in the beginning to talk about sustainable practices with the tenants was quite meaningless. However, one good example was found in the park. During the interview with the pelletizing company sustainability was brought up multiple times. For this company sustainability is a corner stone of their communication policy and corporate social responsibility strategy (Hussein, personal communication, 2017). Unfortunately, this is the only example found in the park. What was also mentioned as an integral part of their sustainable strategy is the implementation of ISO 14001 certification (Environmental Management). This certification makes company take active measures in energy-efficiency and management of waste ensuring responsible end-of-life of their by-products. Few companies in the park are ISO certified. Yet it could be a good way to direct the companies into course of sustainable operations.

R9 Support of the government

Constraints of the role of the government represented by the ministries s have been described earlier in the paper. The conclusion that can be drawn from above said that there is very limited support from the government in terms of integration in the park. In a lot of cases even the opposite could be observed. There are no introduced incentives, subsidies or stimulating taxes that could motivate the industries to adopt more sustainable practices and seriously consider energy-saving measures. The first measure that is going to be applied soon is landfill tax though. The fact that there is no appointed body for the energy issue in the Ministry speaks for itself (Al Shihi, personal communication, 20017). A lot of departments of the ministry are dispersed and have very limited contact with each other (Al Shihi, Halls, personal communication, 2017). Thus, the department of climate affairs do not have sufficient interaction with the environmental division, which deal with the soil, water, air issues as well as marine environment. However, the situation is going to be changed and it is not going to take a decade (Halls, personal communication, 2017). Positive changes may already come up within the three -five years (Halls, personal communication,). But the role of oil and gas prices should not be underestimated here since it could be the main drive both the government and private sector to shift their concerns to energy and recourse efficiency.

5.2 Current state of knowledge capacity

The next step in assessment of the institutional capacity is the knowledge component. This block mainly reflects the answers of questions that the tenants were asked during the series of interview.

Table 4. The evaluation table of knowledge capacity

KNOWLEDGE CAPACITY													
	Overall	BARKA	SinAl	Tibat	Al Qabil	Qurm	ZOZO	Al Bustan	Stomo	Al Hadd	Meth	YITI	SIN St
K1. Experiments, tests, studies	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓
K 2 Knowledge about own residual products	✓	✓	✓	✓	✓	✓	✓	✓	N/A	✓	✓	✓	✓
K3 Knowledge about beneficial by-products of other tenants	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✗
K4 Input from the universities	✗	✓	✓	✓	N/A	N/A	✗	✓	✗	✗	✗	✓	✓
K5 Accessibility of information	✓	✓	✓	✓	✓	N/A	✗	✓	✓	✓	✓	✓	N/A
K6 Available mapping of hot spots or focus areas	✗	✗	✗	✗	✗	N/A	N/A	✗	N/A	N/A	N/A	✓	✓
K7 Evaluation mechanism for potential synergies	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
K8 Accounting mechanism for existing synergies	✗	N/A	✗	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	✓	N/A

K1. Carried out experiments tests and studies

The table above shows that the tenants were inquired whether they carried out any trials and experiments to arrange any linkages in the park or outside. The majority did, which resulted in already existing synergy or the projects recognized as unfeasible. The example for the first case could be the trial period of the refractory carbon rich waste from SINAW Steel in the Electric Arc Furnace of YITI, test of the spent catalysts at the Muscat cement plant. Both of these trials resulted in the viable linkage. And finally ongoing test and experiments with the most problematic waste – slag. As for the synergy that did not appear to be feasible it is the idea of separating nitrogen and oxygen from the emissions of Sohar Methanol, which, in fact, can be potentially used by the fertilizing plant AL HADD and two ferro-chrome companies. Eventually such an important critical success factor as proven technology has not been in place. It was too expensive to separate these two components. One of the conclusions here is that improvement of knowledge capacity does not necessarily always lead to realized linkages because mentioned above critical success factors have to be in place too. However, what improvement of knowledge capacity can give an indication of impeding factors of collaboration.

However, since many more synergies can be fulfilled as shown on the graph with potential synergies there are more trials and experiments to be done. But one of the main hindering factors as discussed

earlier in the paper is obtaining the permit from MECA to carry it out. Since there is very high chance that MECA previously did not have thorough experience with alternative application of a particular type of the by-product, it can make the process of permit obtaining very lengthy. That discourages the tenants even to carry out the trials and bear high transaction costs.

K2 Knowledge about own residual products

As it can be seen on the table the research shows that the knowledge about the own residual products is very profound. The majority of managers can come up with the accurate rate of generation and accumulation of the by-products.

K3 Knowledge about the residual products of the neighbours

The general conclusion concerning the knowledge about any beneficial residual products of the other tenant is – it is the biggest gap. The tenants pretty much informed about the basic operations of each other. However answer to the interview question “if you know any beneficial materials or energy flows from the neighbours?” was negative. On the other hand, six weeks of research provided the evidence that still there are interactions with clear intention to cooperate, e.g. YTHI, SIUICI, Oil Tanking etc. This finding proves the importance of the communication platform, where the knowledge gaps could be fulfilled. Perhaps even more synergies can be unfolded if the function of knowledge transferring and interaction is catalysed.

The platform proposed by the identified champion could help to improve this point. The idea was born back in 2015. It was proposed to unite all the waste generators in the park and create common on-line “waste bank”, which would help to facilitate exchange of materials and resources. The waste and resources streams would be posted on-line and can be seen by all participants. In such a way secondary materials could find a new owner. Despite the support of the idea demonstrated by the tenant the project was not realized because the project was deemed to be too innovative. The actors have not been ready to realize it and mobilize needed resources, which is the indication of the limited mobilization capacity at that time.

K4 Input from the universities

As it has already been described under the heading of relation capacity, the tenants might collaborate with the universities, although it has nothing to do with energy and resource efficiency, beneficial linkages etc. The only major case, which is still to be realized, is forthcoming collaboration with Qaboos University. However, the potential is much more than that. One can take into account current research, which may spark interest for further investigation of the IS potential in SOHAR.

K5 Accessibility of information

The assessment of this indicator is twofold. On the one hand, it is challenging even to establish the contact with the company or a person if you do not know anybody personally or you are introduced. That was the case during the research when several attempts were taken to contact the companies outside the industrial park. On the other hand, all the tenants were willing to share the information about the processes, the inventories and did not mind the interviews to be recorded (except Formaldehyde company). Tentative explanation for this could be the interest of the tenants in the outcome of this research and the useful insights it can provide. On the contrary to the companies outside the park, these did not see any value on spending their time facilitating the research of a foreign student. One can argue that research did not demand the sensitive data, which the tenants

would not want to share. However, as long as the scope of the research is concerned the depth of the information was good enough.

K6 Available mapping of the hot spots and the focus areas

On the one hand, as earlier indicator suggest the tenants are aware of the problematic waste streams. However when it comes to the waste heat and loses the majority of tenants did not see any problems. Common reply was that the plant is efficiently designed and all the heat loses are prevented as much as possible. However, such common practice as cooling down the slag coming out of the furnace at around 1500° C can be seen as a hot spot. Therefore, it can be concluded that the view of the companies about their own weak places in operations is relatively subjective and arguable. However, if the issue is raised during the round-table meetings and clear cases of inefficiency are demonstrated together with promising application that could change common perception. Yet better investigation of this topic is needed before this kind of the event.

K7 Evaluation mechanism for the potential synergies

Even though some tenants know which secondary materials they can use as the replacement, well developed practice of identifying transformations and substitutions is not present. The companies are not that prompt to go beyond their corporate boundaries and think a little bit more ambitious of the opportunities out there. First indications of this approach are there though.

K8 Accounting mechanism for the existing synergies

As it was argued in the literature the adoption of the accounting mechanism, which can capture first economic synergies and on later stages environmental and social benefits, is a valuable element for the actors (Chertow and Lombardi, 2005, Kurup, 2007, Van Berkel 2010). First of all, it helps to realize the real value of the already existing linkages and deliver more convincing arguments for the senior management to proceed with other ones. Capturing the benefits allows documenting the best practices to learn from them and inspire other actors (Kurup, 2007). And finally, accounting the benefits of re-channelling the secondary materials and energy can help to develop and adopt the life cycle thinking and approach for the companies (Kurup, 2007). Even though some of the tenants could from top of the head during the interview make an approximation of the economic benefits of the synergies, the comprehensive accounting is not adopted at the larger scale in SOHAR.

5. 3 Current state of mobilization capacity

Table 5. The evaluation table of mobilization capacity

MOBILIZATION CAPACITY	
M1 Dedicated to synergies resources	✓
M2 Developed waste management system	✗
M3 Available funding for future projects	✓
M4 Diversity of products involved in synergies	LOW
M5 Recruitment procedure of the new tenants	✗
M6 Level of participation and involvement of important actors	✓
M7 Degree of resource reuse	HIGH
M8 Public-Private Partnerships	✗

And the final element of building the institutional capacity is the block of mobilization. The assessment of which will provide a clear a picture of ability of actors to mobilize the resources and stakeholders to implement the synergies.

M1 Dedicated for the synergies resources

Interviews gave the evidence about a number of negotiations, tests and trials to establish certain synergies. It means that financial and management resources have already been channelled for realization of linkages. And these practices are not new and unfamiliar to the tenants.

M2 Developed waste management service

A number of operating waste management companies has been identified within the park. Going through the companies' presentations and getting insight from the interviews and discussion, the majority of waste streams have already found its application. The reason for that the secondary materials have the market value either in Oman or in the other countries.

Interestingly, the common practices are that the tenants did even need to look for the operators, these approached the companies themselves. However, perhaps the same materials which went to the waste operator could be used within the park avoiding the costs of transportation and delivering the value inside the park. It is not critical though for the tenants to find application of waste within the park. More than that from perspective of the tenant it does not really matter, where will the waste go as long as it is disposed in the responsible way and left the premises of the company. This practise is common also in other countries unless movement of waste is limited by the proximity principle as in the UK and UEA. In case of UAE the waste cannot even leave the boundary of an Emirate.

As for the most discussed waste stream in the park, iron and ferro-chrome slag, the re-use and alternative application of this material still remain a big unresolved issue. However, as literature shows in can be utilized in a wide number of application ranging from utilization in construction and building industry, as material for the waste water or gas treatment, fertilizers, agriculture product (Yi et al., 2012, Taha et al. 2014, Wei et al., 2014, Zhao et al., 2017, Shi 2004). However, since there are no standards for its utilization, scientific evidence (research) and existing pilot cases, this materials still remain to be waste.

Analysis of the current waste streams showed that there is still a big window of opportunity on how the waste management system in the park can be improved. Some waste streams were identified, which with the adequate treatment and processing practices could have further market value within

Oman: wood, wax and oily sludge. It is potentially interesting business cases, which need however the support to take off.

M3 Available funding for future projects

In the Master Plan it was recognized that “synergies in cluster often require active investments. For instance, in pipeline infrastructure that connects all the companies in the cluster as well as infrastructure for re-using heat and steam. Investments that create synergies make all companies more competitive (Master plan, 2017)”. To some extent this statement gives some kind of assurance of commitment of the industrial estate authority to dedicate some resources for the development of synergies. However, if main beneficiaries of a synergy are the companies between whom the exchange is established the financial involvement from part of SUR is expected to be quite limited. On the other hands, if the investment can deliver return on investments and additional revenue stream for SUR and result in the positive benefit, it would be of interest for SUR otherwise not.

Answers of the respondents in park with regard to available resources were mainly referring to convincing business case for them. If the synergy has potential advantage then companies would be willing to consider the options and move further with the implementation (Mohd, Hussein, Murudanandam, Singh, De Jager, personal communication, 2017). What has also been taken as a good indicator is sponsoring relevant researches, test and trials including almost all the companies in the metal cluster. These points provide a proof for good mobilization capacity.

The research that is coming up that has potential to enable re-use of slag requires financial participation of the companies that generate slag. The reason behind participation of the companies has been described among the main drivers, which is twofold: anticipated high cost of the waste disposal and congested premises with waste. None of the waste streams has such critical accumulation rate and stored volumes. As for the first driver, TIWI is aware of very high accumulation volumes of slag and has already announced a very high tariff per ton of slag. Therefore, the companies are under pressure of potential avoided financial damage in case the slag has to be landfilled at a charge (Nissen, De Jager, Ambusaidi, personal communication, 2017). And, obviously in case of successful outcome of the research companies could benefit significantly. All these factors allowed SUR to take a lead and come to agreement and share the costs of the research among the main stakeholders.

M4 Diversity of the products involved in synergies

SOHAR claims itself to be “a strongly integrated Port complex consisting of various sub-clusters” (Master plan, 2017). In order to prove or disprove this statement it is necessary to take a closer look at the existing state of the synergetic exchanges. To do so the chart of the present synergies was created (Figure 9). From this chart it can be seen that the number of the actual synergies between the companies is pretty limited. Among the products that are involved in the exchanges are the following: cast iron, refractory carbon rich materials, scrap metals and the steel slag. The rest of the streams are channelled to the waste operators, which valorising them. As it has been discussed earlier these supply synergies or transactions based on normal commercial terms were left out of the scope of current research on industrial symbiosis.

M5 Recruitment procedure

As far as industrial symbiosis is concerned the recruitment procedure for accommodation of the new tenants plays a big role. The procedure might entail: search, selection and further

accommodation of the new company. However, it has been identified that the current practices do not include any symbiotic considerations. Rational behind the choice of the projects is purely commercial and depended on approval of the overlooking ministries, such as Ministry of Environment and Climate Affairs and Ministry of Commerce and Industry (Al Omairi, personal communication, 2017).

Nevertheless, there are some good examples in the Port of Sohar. One of this is on-going process of accommodation of the asphalt company. The decision to proceed with hosting a new industry came without consideration of the potential synergies the new neighbour can provide. In fact, the research has shown that a number of the by-products from steel and ferro-chrome manufactures can be streamed to the asphalt production and be used as an input material (Yi et al., 2012). Another example of the successful developments in the park is hosting a new polymer company in the petrochemical cluster. However the decision to place this plant was motivated by a flagship company within a petrochemical cluster called AL QABIL, which incorporates other three plants under the same name. This project is both beneficial for AL QABIL itself and the port as a whole from point of view of the potential synergetic opportunities between the companies in the cluster. This project is a typical continuation of the value chain for the oil based products. Therefore, a lot of materials from the existing oil refinery, aromatics plant and polypropylene plant can be channelled to the new plant.

M6 Level of participation and involvement of important actors

It is important to look into this aspect, because it indicates the quality and the time line of the learning process. The higher level of participation would be the more chances of reaching common consensus and proceed with the resolvment of the common concerns.

Several proxies have been chosen to come up with the conclusion about this indicator:

1) CO² inventory study conducted with the support of Ministry of Oil and Gas in 2015

Regarding CO² inventory, the reports and business correspondence has shown that 9 tenants were of interest for the study. In total 7 tenants have provided needed data and two has rejected for unknown reason, YIII and AL HAJAR. However, as the rest course of the research shows these companies are usually open for collaboration. That provides positive indication of the level of participation.

2) Level of participation during the first attempt to encourage development of IS

It is worth referring to the initial presentation of the concept of industrial symbiosis and “waste bank” as the first step carried out by Steve Halls and described in the section of “champion”. These series of work-shops have been very well perceived. The level of participation was pretty high and tenants supported the idea of the “waste bank”, which is still present among the tenants.

3) Participation in the upcoming study on the re-use of slag

As it has already been mentioned the companies within the metal cluster supported the idea of taking part into the research on alternative application of slag. Participation of TIWI, and the ministries is to be confirmed and still pending. If TIWI agrees to participate that would provide significant impact on improvement of mobilization capacity and building common understanding around the collective issues.

Coming back to fact that SUR and BARKA are trying to get more actors on board to solve the slag problem also provides an evidence for another important element of the mobilization capacity. That is mobilization of the rest of stakeholders to solve common issues.

4) Amount of tenants that committed to support this research on Industrial Symbiosis

And finally, when it comes to the present research it has to be said that almost all the tenants and other stakeholders with the minor exceptions has agreed to contribute their time and efforts. During the interviews a lot of internal issues have been discussed and certain information was available upon the request.

Summing up all four chose proxies demonstrated high level of participation of the tenants in the initiatives originated in the park.

M7 Degree of the resource reuse

Established practise and philosophy of recycling and reusing in the park can create a good basis for implementation of the exchanges. If the company learns how to re-use their own resources be it materials or energy, it can perhaps be open and receptive to use other actors' secondary streams and be open for further substitution. For instance, YITI is already reusing their filter dust in exhaust gas cleaning. During the interview a new possibility was discussed: to recover the heat lost from cooling down of slag and putting it back to the process for heating up the material before it goes to the furnace. The source of the heat loss can be both internal or external.

The only source of the information to access this indicator became interviews with the tenants. Perhaps the auditing could show different results, but it can be concluded that all the tenants to the certain extent practising resource reuse (e.g. water, filter dust). However all the tenants have been similarly claiming that they have no problems with the heat loos, which is very arguable.

M8 Public-private partnership

There are no present public-private partnerships in SOHAR Port & Freezone. The only attempt which is undertaken in the park is in the field of Health & Safety is to arrange shared fleet for the emergency response purposes such as fire trucks, emergency and so. One of the mentioned in the interviews challenges is to attract private sector into collaboration with the authorities or governmentally owned companies (Halls, personal communication, 2017). However, more and more forums of this sort are coming up with the intention of bringing these actors together.

However there is another perspective of how PPP dimension can play a role in improving mobilization capacity. The government can facilitate IS together with the private enterprises and actors. The example for this is set up of such program as National Symbiosis Programme (NISP) founded in the UK (Abhishek, 2011, Paul et al., 2012, Velenturf, 2017). NISP played a critical role of setting the course to industrial symbioses and encouraging all other actors such as private business, authorities and academia to get on board. Moreover, this publically funded program was identifying and managing the resource partners for future collaborations, setting up the common vision, which is the clear role of the relationship-broker and orchestrator (Paquin and Howard-Grenville, 2012). One of the functions of the private sectors was to facilitate the cases studies, which helped to improve the knowledge capacity and result in mobilization of the resources (Velenturf, 2017).

Taking MECA as an example, there is an understanding the importance of PPP and its positive prospects (AL Shihi, personal communication, 2017). However, no resources have been dedicated so far to encourage formation of PPP. To do some the Ministry would have to be able to prepare, negotiate and implement this type of arrangement, which might be a challenge at the first stage. As for the national program facilitating industrial symbiosis it requires really profound awareness, commitment and environmental pro-activeness on the governmental level, which is currently not there.

Issue of the business models and contractual agreements

Business-models

In the finding section several examples were given of unsustainable business models prevailing in the park. The companies stick to their core business without considering potential opportunities of new value proposition, its creation and capturing. New way of thinking is needed to look into existing models.

For instance, Oil Tanking can create a new value proposition by introducing new product to the market – liquid spent fuel. By new value creation they can understand a process of distributing it to YITI being paid for the material, which is refers to value capturing mechanism. By doing this Oil Tanking will utilize several archetypes introduced by Bocken and colleagues (2014): maximization of the material and creation value from waste. When it comes to TIWI the same archetypes would be utilized as in case with Oil Tanking if TIWI stats work in recycling and reusing business, which is reasonable for the flagship waste management company in Oman. Another archetype of adoption of stewardship role could potentially be valuable if, for instance, TIWI ensured better support for the industries with finding an operator for them. Such department with similar function is already existent, but apparently needs more resources. Therefore, TIWI can also alter its value proposition and creation.

Two potential development opportunities were proposed and discussed through the lens of innovative sustainable business models. It can be seen that eventually significant environmental impact can be achieved, some material loops cab be closed, which speaks in favour of embedding principles of circularity.

Contractual agreements

Another important aspect to take a look is existing contractual agreement between the companies. First of all, it will help to understand on which level the development of integration is and derive valuable lessons for further recommendation. Secondly, it will be possible to high light valuable best practices.

There are number of established synergies within the port, which can be seen on the figure 9. As soon as trial tests are successfully completed, commercial departments of the involved tenants give the green light to the feasibility of the project, the exchanges would be formalized between the parties. Most of the synergies which are taking place on the constant basis are formalized in the contractual agreement with the specified transportation arrangement, price of the materials, its quantity and so on. What was also discovered is a practice of collaboration based on “on-call contracts”. The example could be the contract arranged by the anchor tenant AL QABIL. Basically it means that AL QABIL calls for the waste recipient company to collect the waste only when it is

available, which might be quite inconsistent. However, found consensus was to state a minimum expected quantity to secure the supply for the recipient (Al Saidi, personal communication, 2017).

Furthermore, another the important feature of the agreements has been mentioned by SINAW Aluminium. Since the companies have limited experience in utilization of the by-products, recipients take the materials with high cautions. The main concern is the effect on the operation and final quality of their product. Therefore, the existing agreements between the tenants are for one year with further intention of re-visiting the terms. During this year both parties can adjust their practices accordingly and develop trust (Innes and Booher, 1999). On the other hand, there can be a less willingness to invest the resources in one year project. The actors might be less prompt to dedicated significant investments for one year collaboration. However, one should keep in mind that it is just first stages of developing long-term collaboration.

Among the challenges to arrange the agreements were mentioned distribution of the responsibilities: cost of transportation, obtaining the environmental permit, responsibility in case of toxic emissions etc (Al Reesi, Al-Muqbal, Azevedo, Lobo, Singh, personal communication, 2017). These points come up and add complexity to finding a consensus and establishing the agreement within reasonably short period of time.

Another finding indicating the early stage of the development of the contractual agreements is referring to the existing business models. After two years of struggle AL QABIL is sending its by-products to the cement factory free-of-charge. It considers it as the first stage of developing the collaboration. Once the linkage becomes solid there is a possibility of revisiting the agreement between the parties again.

Therefore, it is a good model for other actors in the park on how to approach an establishment of the partnership. A lot of lessons can be learnt from here. First of all, about the evolution of agreements: trial -> gradual learning process of adjustments the practices and operation for new secondary materials -> call-on short-term contract, free-of-charge basis of partnership -> gradual evolvement into long-term arrangement. Along the whole process the trust is being developed between the actors, which is facilitating the whole collaboration.

5.4 Identified roles and functions within the park

This section is going to be divided in two parts. First, it will go about identified role in the context of SOHAR. Then the attention will be drawn to absent or underperformed functions. Since the functions of the different roles are overlapping the main conclusion will be summarized in the table comprising the evaluation of the enabling functions found in the literature.

Anchors

The company called AL QABIL, which gathers under its umbrella an oil refinery, aromatics and polypropylene plant, can be regarded as an anchor tenant in the whole park. There are two prime reasons for that. First, AL QABIL provides the largest flow of the by-products and materials seen in the park, which are utilized within the same petrochemical cluster and the rest is available for the outside consumers. The other reason why AL QABIL can be seen as an anchor tenant is the fact that it put the proposition forward to accommodate a couple of new tenants, which will comprise a chain of polymer processing. It allows AL QABIL to expand the processing chain of the oil based products.

AL QABIL has compiled the list of the available waste streams, which are not currently used and mostly disposed by specialized company or sent to the landfills. It can be seen there are still a number of materials that have inherent value and can be further utilized, for instance spent catalysts, refractory, asphalt and so on (Al Saidi, personal communication, 2017). In fact, availability of such list of available streams is an important element for support of knowledge capacity in the park. If more companies have it, which, in fact, is the case (YITI) then action can be taken to better utilize and exchange of these resources. For instance, in order to create the inventory on the park level this information would be of great benefit. That means that the role of AL QABIL as the anchor tenant can be enhanced and more synergies might be established.

Champion

Such a leader, who encourages proactive actions towards sustainability on a general level and industrial symbiosis on a park level, was found during the research. Such a person was identified on the governmental level. He pushes the agenda of industrial ecology, energy efficiency and sustainable development.

He is a Senior Advisor for MECA and from 2013 he has been a director of the environmental research department of Sohar University. He attempted to spread an idea about integration and resources efficiency, mainly focusing on waste issue. A number of meetings with the tenants and industrial estate authority were held with the goal to initiate some collaboration between the parties. These had an aim at improving the relation capacity within the park. One of the proposed ideas was to create a web-platform, where available waste streams would be posted and exchanged between tenants and other actors in the region. In this manner the resources would be mobilized with the help of so called on-line “waste bank”. In terms of institutional capacity, that would have a positive impact to large extent on knowledge capacity and to less on mobilization one.

In fact, this idea is still circulating among the companies, which has been noticed during the interviews. In fact, the initiative was brought up during the interview by the tenants itself without and leading question or mentioning of Steve’s job. The tenants did refer to him and spoke highly of the initiative. However, there was nobody to bring this idea further and realize it, which is the evidence of lack of mobilization capacity at that time. According to Steve, the reason why it faded

away was “that idea was too ahead of time and neither management, nor authorities were ready for that yet” (Halls, personal communication, 2017). The other convincing reason and perhaps the consequence of lack of initiative from the higher level was the absence of the appointed personnel or a steering body as brought up in the literature. The body that would play a facilitating role and save the tenants trouble to divert the attention from their core operations. It has to be added that partially Steve played an orchestrating role by encouraging managers to act more entrepreneurially and go beyond common firm boundaries. Therefore, that provides the evidence of the limited mobilization capacity at that time.

Ever since the number of interaction with the agenda of Industrial Symbiosis has reached 10-12 times (Halls, personal communication, 2017). Slowly but steadily he is preparing the ground for the seeds of IS to grow and flourish. Not only innovative waste management practices have been a focus for Steve, but also other problematic issues in the park. The best example would be his active participation in resolving the slag issue. Working in the Ministry he is trying to improve knowledge capacity of MECA, which eventually can have a positive impact of improvement of the institutional context. Therefore, Steve Halls can be called a champion making overtime a positive impact on relation and mobilization capacity as proved the examples above.

Brokers

There are certain activities, which indicate that the role of a broker to a certain extent is performed by SUR, an industrial estate authority. SUR have power and authority to foster synergies in the park to bring it on another level of environmental development and technological advancement.

Having such shareholder as Rotterdam Port, which is also a good example of the port, where industrial symbiosis is realized (Baas, 2008), helps to bring cutting edge knowledge and management experience in the port. There are a lot of lessons to be learnt from the experience of Rotterdam Port with IS. Therefore SUR can play a role of knowledge broker bringing to SOHAR practices and experiences relevant for development of IS. The existing knowledge is transferred through, first of all, an experienced Dutch employee, who is responsible for environmental management in SOHAR. And secondly the experience is shared through trainings offered by Rotterdam Port in the Netherlands. The same channels can be used for transferring the knowledge about IS.

Another brokerage role of SUR is negotiation with TIWI to drive down announced landfill charge for the disposal of slag. At first, announced fee was relatively high: 7 OMR per ton. Taking into account that as of now there are more than 400.000 tons of slags, it would result in very high financial loss. Therefore, SUR is being a mediator in these negotiations trying to represent the interest of the companies and bring the fee down. One of the arguments that was used by SUR is that TIWI should give the opportunity for the companies to find an alternative application of their waste rather than right away make the companies to dispose their slag and pay so much.

Service-intermediaries

The research has shown that the function of service-intermediaries including presence of scavengers and decomposers is well represented in the industrial park. One of the examples up until recently was the Dutch company (KVA Int), which on occasional basis was taking spent catalysts from the oil refinery and sent them by vessel to Europe (Kouwijzer, personal communication, 2017). Other examples of the service-intermediaries are three energy companies located in the park, QURM a water supplier and Air Liquid, which is a gas and compressed air supplier.

The situation with the operating waste management companies within the park is more complex though. On the one hand, there are a good number of the scavengers and decomposers, which are taking waste from the tenants. There are certain examples, which provide evidence for the positive shift of attempts to find application of its waste among the tenants. For instance, there is a linkage of SINAW Aluminium with YTTI, AL HADD tried to approach AL QABIL etc. The tendency still needs to be facilitated though with the help of brokers. The tenants are willing to find alternative application of their waste due to the pressing problem of the congested premises and upcoming landfill fee. It was also multiple times mentioned that the tenants sometimes agree to get rid of it free of charge provided the transportation expenses will be taken care of by the recipient as in case with AL QABIL.

Coordinator

Looking into the future SUR has just conceptualized the vision to make “the world’s first self-sustaining Freezone cluster” (Masterplan, 2017). The cluster is visualized to be a highly integrated zone with a lot of alternative solutions for power and incorporated units supporting sustainable operation of the park. For instance there is a solar panel zone, fish ponds, battery park, cooling unit running on hot water etc (figure 8). Formulation of the vision is one of the functions of coordinators as described previously in the literature review section. Adopting this vision also implies commitment to invest in knowledge and relation capacity, which SUR can do and is vital for realization of the vision. Keeping in mind that just an idea is not enough to bring the action forward, further steps should be taken for realization of the vision. Due to the fact that the vision was recently formulated no actions have been taken yet to communicate it to the tenants. However it is important foundation for aligning the interests in the park, visions of the tenants and eventually mobilizing resources for the realization of the vision. What kind of vision is missing though is the one expressed by the government about sustainability targets and depletion of renewable resources.



Figure 8. Projected vision of the park

It should be noted that SUR is trying its best to ensure waste minimization within the metal cluster by enabling the iron and Ferro-chrome companies to find an application of their by-product (slag). As widely practiced around the world instead of piling up the slag it can be used in a number of applications, which SUR is trying to facilitate. For instance, SUR is constantly maintaining the dialogue on this issue with the Ministry of Environmental and Climate Affairs and governmentally

owned waste management company TIWI. SUR is trying to help to re-classify the material from the “hazardous waste” and advocate safe and beneficial application of slag.

Furthermore, SUR organizes monthly round tables on Health & Safety and Environmental issues. The main goal of these gatherings is to bring the actors together, discuss common issues, share the updates and knowledge and therefore to improve relation capacity in the park. Here the role of relation-broker is clearly evident.

Orchestrators

Continuing about SUR it also plays an orchestrating role. In case any infrastructure is needed to support the linkages, for instance, recovery of the waste heat, industrial estate authority can facilitate this project.

Furthermore, one of them can be initiated by SUR a research upon the reuse and application of the slag by other industries. The study was proposed by the port authorities to involve the most prominent research university of the country called Sultan Qaboos University and other important stakeholders such as MECA, TIWI, Ministry of Transport and Communication, Ministry of Commerce and Industry. Next to it, SUR performs another function of the orchestrator, which is ensuring well-functioning of the actors. If there is any problem the tenant face they can reckon on support from SUR. And another demonstration of this function is monitoring of the air quality in the park and in case something goes wrong, SUR addresses the problem. These existing practices could be valuable in facilitation of future linkages between the companies when industrial symbiosis will become more mature.

The current role of government

As it was pointed out in the literature review government interventions aimed at improving resource efficiency among industries can significantly advance IS (Costa et al., 2010). Analysing potentially enabling mechanisms that government is responsible for the following could be said about SOHAR. As of now there are no targets or national objectives that can guide the private sector. As was mentioned by Gertler (1995): “Economics alone will bring you a certain amount of symbiosis. To go further, you need political impetus to require pollution control technologies and/or to adjust prices to make symbiotic arrangements economically viable”. The same can be observed in SOHAR. There are already certain business cases that serve as a foundation for symbiotic linkages such as between SINAW Aluminium and YITI. However, limited numbers of the economic incentives and regulatory instruments that can encourage more symbiotic exchanges were identified. One of these is the landfill fee that TIWI is trying to impose on the slag manufacturers.

Other absent and underperformed functions

Analysing institutional context of SOHAR some functions have not been identified in the park at all.

- There is no intermediary, who is monitoring the waste markets to mobilize the by-products generated in the park.
- The function of encouraging local buy-in, which was previously performed by the champion, is evaluated to be low since it is not currently performed.

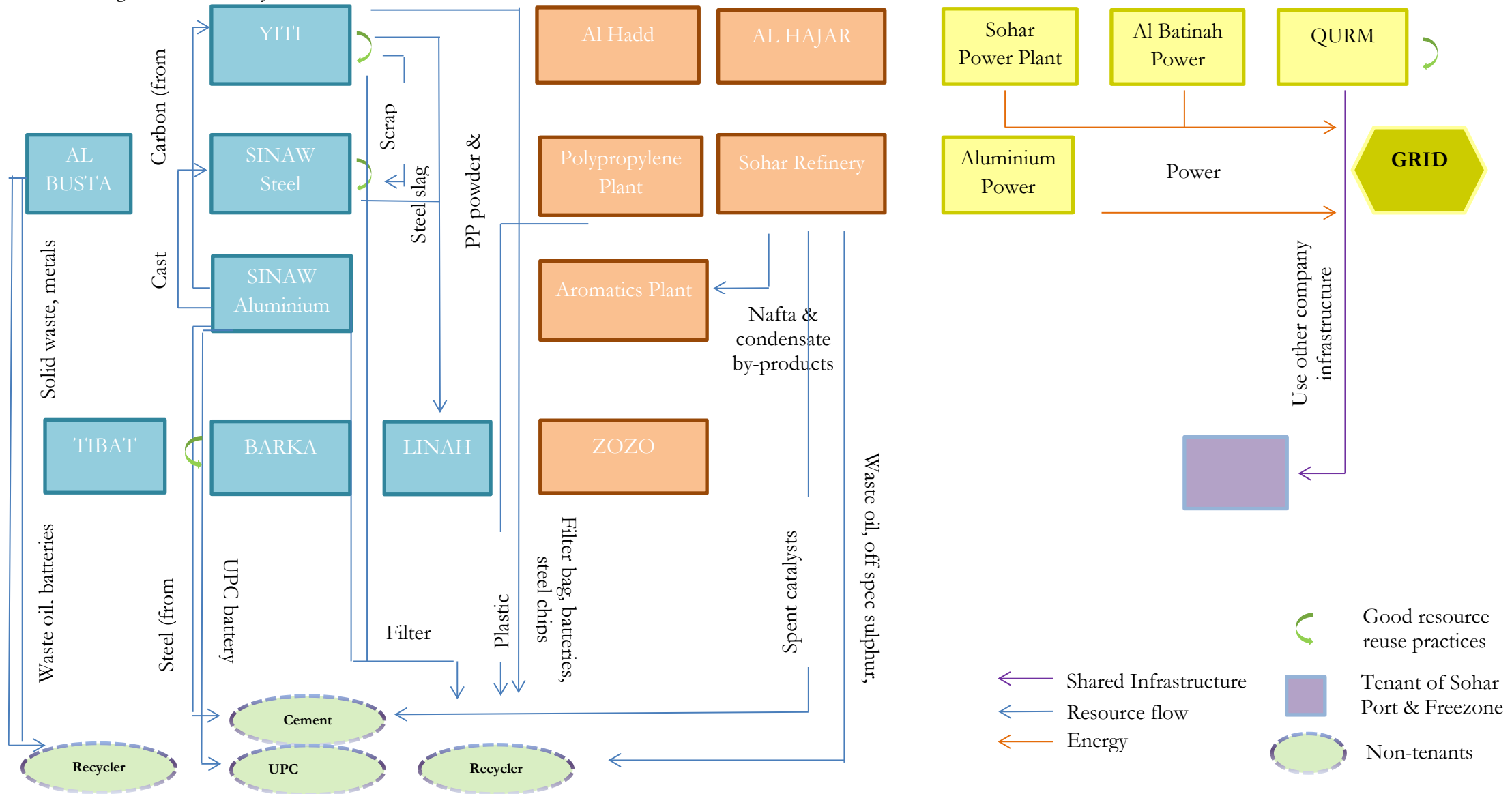
- If the feasibility studies are carried out with the aim at identifying viability of the synergy, then it is done by the companies itself. However, the park would benefit if the synergy identification study would be carried out on the park level.
- Managing of non-core business of companies was deemed to be low, because there is big field for improvement. However, it would be unfair not to mention that SUR facilitation of the slag issue is the vivid example of managing non-core business of tenants.
- The function of obtaining and sharing knowledge, provision of educational services was evaluated to be low. Even though SUR carries out monthly HSE meeting it does not always have an environmental agenda. Furthermore, provided training to the companies so far had nothing to do with energy and resource efficiency, identification of linkages, which should be done to improve knowledge capacity.
- The point of creation and facilitation of local institutional conditions refers to weak role of MECA and overlooking authorities as institutional anchors.
- Even though the point of the facilitation the connectedness and managing interaction was evaluated relatively high, there is still a lot to be done to improve relation capacity, which encompassing these elements.

Table 6. Presence and quality of the enabling functions

The presence and quality of the enabling functions		
	Presence	Quality
Policy interventions	✘	
Monitoring the markets	✘	
Encouraging local buy-in	✓	low
Resolution of the conflicts	✓	high
Carrying out feasibility studies	✘	
Building trust and commitment	✓	high
Physical exchange of the secondary materials	✓	high
Ensuring well-functioning of the present actors	✓	high
Managing non-core businesses of the companies	✓	low
Providing managerial and infrastructural support	✓	high
Promotion of exchanges and eco-efficiency strategies	✘	
Identification of potential IS synergies and partners for it	✘	
Obtaining and sharing knowledge, provision of educational services	✓	low
Creation and facilitation of local physical and institutional conditions	✓	low
Managing interactions and the social linkages between different actors	✓	high
Facilitation the connectedness among the actors ensuring their cohesion	✓	high
Managing the stability in the network by recruiting new tenants or suppliers	✘	
Pulling together the dispersed resources and capabilities of network members	✓	high
Setting up, communicating and enforcing long-term objective vision for sustainability	✘	
Provision a critical mass of resource and energy flows for symbiotic linkages to evolve	✓	high

CURRENT SYNERGIES

Figure 9. The current syne



6 Discussion and Recommendations

6.1 Report on done interventions

During the field work there were a number of interventions have been done. The aim that these interventions pursued was to improve the institutional capacity and influence the actors to come together and uncover the potential of IS.

Revealing new opportunities for slag

One of the first changes that were delivered for knowledge and relation capacity has to do with the problematic waste steam – slag. Forthcoming research on re-use of the slag has already been mentioned multiple times throughout the research. But SUR wanted to get a new perspective and find out more about alternative applications of slag. Apart from presented overview of the multiple sources of slag application (Yi et al., 2012, Taha et al. 2014, Wei et al., 2014, Zhao et al., 2017, Shi 2004), during the literature review a case in GCC was found (Taha et al. 2014). In the article interesting and quite useful information was obtained. Namely it was stated that Qatar experiences the same problem with the slag, however their volumes for the whole country are the same as in the park of SOHAR alone. The same line of thought was present there with the engagement of the stakeholders and carrying the research to obtain a scientific evidence of slag re-use and stakeholder approve. However, the driving force for Qatar is the fact that they are purchasing the aggregates for construction from Oman. And therefore slag would help them to become more independent and decrease the costs of the construction projects (Taha et al. 2014). This information was communicated to SUR with the identified opportunity of cooperation. As a result the management is utilizing their network to get in touch with the decision-makers and already building up the strategy for the potential deal with Qatar and SOHAR slag. Thus, this new business opportunity can be attributed to new knowledge that the current research has delivered.

This example also provides an academic value for the research and manifests institutional capacity. It illustrates another case of collective actions to address a common issue, mobilization of stakeholders, developing the mutual understanding and acknowledging the importance of the problem on the national level.

Coupling the actors together

Another contribution to the relation and knowledge capacity became identified synergy between ferro-chrome companies and foundry industry, which in this case is SINAW Aluminium. Murthy and Rao (2016) in their recent article claim that ferro-crome slag can be used as a mould material for the certain degree replacement of the silica (moulding sand) in the foundry industry. Got this knowledge both parties can contact each other and discuss potential of this idea. It was observed that nobody is familiar with this option and the representatives of the companies were pretty sceptical about it. The research was circulated among the managers of all parties concerned. It is hard to access what kind of resonance it delivered due to limited amount of time spent in the park. The managers of SINAW Aluminium also warned that these kinds of decisions would take long to be discussed and assessed before anything tangible arises.

Presentations for the key actors

And finally after the reference state was defined, preliminary conclusions over institutional capacity and the context has been drawn, strengths and weaknesses became evident, and two presentations were carried out. One presentation was for the industrial estate authority, which included the findings, potential opportunities of IS, recommendations how to move forward etc. Another presentation was given to the tenants having pretty much the same content, but tailored specifically for the interest and challenges. Apparently, it is not the first presentation of this kind, however in this case more limiting factors of industrial symbiosis were discussed and several tenants actively participated in the discussion. Moreover, the opportunities that were specifically identified for SOHAR were demonstrated, which is more valuable than demonstration of potential of IS in general.

As the internal presentation for SUR the research findings and recommendations were highly welcomed and thought of as really relevant for the company. The recommendations were taken seriously and communicated to the CEO. In fact, CEO is known to be very pro-active and open for innovations. Moreover, the managers from the environmental department were very enthusiastic about such ideas as revival of the “waste bank” initiative, platform for communications and energy study on the park level. This feedback gives the first indications of the improved institutional capacity since 2015 when the idea about waste bank has introduced. Another indicator is the approval of SUR for this research, provision with all the necessary support in terms of arranging the meetings, giving access to internal documentation etc. Therefore, it can be concluded that the understanding of the common concerns became more mature and the opportunities and benefits that IS can bring became more comprehensive. This dynamics can be attributed to improving knowledge and relation capacity.

Concerning the presentation to the tenants the following aspect should be highlighted. First of all, due to limited available amount of time for the field research a very short notice was given to the tenants to attend the presentation. However, all together around 25 people were present representing around 8-10 companies from the different clusters. To increase the dissemination of knowledge, SUR will be responsible for circulating the findings and recommendation among the companies. Secondly, the presentation has sparked the discussion among the current barriers for the tenants, including MECA and TIWI. SUR stepped into discussion assuring their support. All the tenants agreed about the lack of communication in the park and between each other.

Thirdly, during the presentation new opportunities for residual resource utilisation between the tenants were described to spark the interest for further negotiations. Apart from it, the materials, which the tenants can offer, were also briefly mentioned. These can potentially comprise “the waste bank”. Therefore, it can be concluded that this single face-to-face gathering contributed to the improvement of the knowledge and relation capacity. However as argued in the literature this sort of presentation might have far-reaching effect. “This is consistent with findings elsewhere: once local stakeholders have discovered a particular synergy, and assess the industrial system properly, they typically uncover many more existing and potential symbioses.” (Van Berket et al., 2009). It may be enough for me just to give a push and introduce the opportunities, find the right actors, show convincing arguments and the rest the companies will do themselves.

Therefore, the actors of the park should familiarize themselves with the outcome of the study, take away important messages that are relevant for them and keep improving the area that need attention and pursue further development of industrial symbiosis in SOHAR Port&Freezone.

6.2 Strengths and weaknesses of the institutional context of SOHAR

RQ 1 What are the strengths and weaknesses of the institutional context of the SOHAR for industrial symbiosis to evolve?

Institutional context is shaping the opportunities, which the actors see for themselves. The local institutional context for of SOHAR Port & Freezone is not an exception and has its own unique mix of strengths and weaknesses, which influencing the actors decision and strategies with regard to industrial symbiosis. Starting to draw a holistic picture of SOHAR context the advantages of it will be first one to be mentioned.

Initial scoping of this thesis left existing supply synergies aside. However it has to be said that it is already a good foundation for more complex synergies based on by-products and secondary streams to evolve. Moreover, there are already some examples of collaboration in the park based on extracting value from the resources that otherwise would be discarded. For instance, partnership between YITI and SINAW Aluminium provides a good example of evolution of a synergetic linkage; the process of formalization of contractual agreement, the practice of helping each other to overcome regulatory barrier to make the collaboration happen. These synergies provide good cases to learn from, replicate and to build upon.

Among the other strengths that can be highlighted is the recently adopted vision, which commits to further integration in the park and encourages innovation. However, it still needs to be communicated to stakeholders to get them on board for its realization.

There is one more positive example related to slag that should encourage the whole park for further great work. The course that is taken by the tenants and SUR to address the common problem shows the ability of the actors to find a common understanding of the tackle the issue. It also illustrates efficient function of the role of coordinator, who is pulling the actors and resources together to solve the problem, reconciles the conflicts and tries to negotiate preferable conditions for the actors. Moreover, such functions as anchorage and champion are present in the park, which are enabling development of IS.

Describing the state of the waste management, which also plays a role in the institutional context, there are few types of waste streams that found in the park are valorised by the waste operators outside of it. The market for some streams is present in Oman. But much more value is to be extracted from waste and to be captured within the park or create synergies on regional level between the industries.

Unfortunately, there is also relatively big indication of impeding force for the development of favourable institutional context of TIWI being granted a mandate to be the main company responsible for the waste management in Oman. The multiple evidences were provided suggesting despite its major role, TIWI's support in resource exchange, re-use, recycling is very limited. Sometimes, it is paralyzing the actors in their good intentions to adopt circularity approach.

Moreover, there is inadequate regulatory support and guidance on resource efficiency measures, which is in MECA's area of responsibility.

Another serious drawback, which is impeding industrial symbiosis and principles of circularity, are prevailing linear business models adopted by the actors. Not being captured within value proposition and value creation strategies; recycling, exchange and reuse approaches are not given enough attention in the park.

One of the major weakness is of the institutional context is the effectiveness of the Ministry of Environment of implementing principles of industrial symbiosis. The lack of expertise and political will of promoting reuse and recycling activities, absence of the adequate standards for it and considering "waste" as "waste", but not a "by-product" that all does not create favourable foundation for development of industrial symbiosis. Another important missing element is regulatory and economic pressure applied against polluters guided by national sustainability targets. More specifically, combination of high availability of cheap fossil fuels and absence of laws and market based instruments stimulating energy efficiency is major limiting factor for development, for instance, energy based linkages.

6.3 Recommendation on the improvement of institutional capacity

RQ 2 Which interventions of local actors will positively impact the institutional capacity of SOHAR Port & Freezone to advance industrial symbiosis?

Before answering the research question it needs to be mentioned that some given recommendation resonate with the UNEP document "Recommendations for Management of the Industrial Estate", which confirms that the author of this paper was on the right track. The answer is divided into several parts: recommendations on interventions concerning institutional capacity and guidelines on potentially interesting areas for the future synergies, which can be useful for the coordinator.

Knowledge capacity

Carry out an energy study to map out hot spots, waste losses and inefficiencies. There is very limited knowledge about this topic among the tenants. Efficient use of energy and resources is of prime interest for the industrial estate authority since it is supplying energy for the tenants. Moreover according to Vision and Masterplan competitive and clean energy is critical success factor for future development. Therefore, application of the waste heat, solar potential is worth to be explored.

Revive the initiative of the "waste bank", which is still very much in favour among the tenants. To begin with it is necessary to encourage the tenants to create inventory of their waste and secondary materials, which can be of interest for other tenants.

What also can be done by SUR is to encourage sharing of knowledge and experience exchange about Industrial Symbiosis from the Port of Rotterdam. It can be done through specialized workshops or trainings carried out by the Dutch colleagues, who are responsible for IS in the Port of Rotterdam.

Three following recommendations are derived from the identified weaknesses of the knowledge capacity during the interviews. One of the gaps that should be bridged among the tenants is the knowledge about the other companies in SOHAR Park. The tenants should be aware of what the

neighbours have to offer and how their by-products and energy streams can be of value for them. This knowledge exchange can be facilitated through the platform for interaction suggested for SUR. The push is needed to encourage the companies to go beyond their corporate boundaries and initiate the learning process.

One of the beneficial practices which tenants can incorporate is the adoption of the accounting mechanism for existing synergies. Quantification firstly of the economical and then of the environmental and social benefits will be valuable for several reasons. First of all, especially quantifying the environmental benefit might help with negotiations of MECA. The authority will see the value behind the synergies, which might ease the process of the obtaining the permits for other trials and projects. Quantification of the economic benefit will be convincing for the senior management to work further on that front and maybe even to attract new partners for cooperation. One way to approach is to leave it up to the tenants or more systematic one to introduce the template by the coordinator, who will be responsible for developing of IS. And then circulate it among the tenants, explaining the mechanism behind it.

Relation capacity

Formalize the platform for interaction. It has been noticed that there is lack of interaction between the tenants with the purpose of collaboration and solving common issues. Monthly meeting similar to HSE committee should be organized with the clear environmental agenda, where synergetic opportunities can be discussed too. It will help to establish a platform for communication, where the tenants can fill up the knowledge gap about beneficial products of the neighbours, inform about their available materials for the exchange, discuss common issues. It would also encourage the knowledge transfer and therefore improve knowledge capacity. Another important role of the platform could be also the opportunity for SUR to share the concerns about heavy reliance on the fossil fuels and ways to diversify the energy mix. Moreover, during these meeting the formulated Vision can be communicated to the tenants and further action for its realization thought through and discuss. In fact, more efforts should be focused on communication and realization of the Vision since it is a powerful tool to align the visions of all the actors. Moreover, referring to Vision a set of actions can be jointly formulated to realize it.

The recommendation which will improve both relation and mobilization capacity is to enhance the interaction with MECA to motivate right regulations. These are such regulations that will urge the tenants to take seriously energy-efficiency measures and conservation of the resources.

Furthermore, opening up to academia and join the research interest and operation needs can be a good combination to move forward industrial symbiosis agenda. Perhaps attracting thesis researches and interns to work on energy and resource efficiency will open new horizons and change the perception of “we have the best optimized plant”.

The companies should learn how to become open-minded for new ideas, innovations and ways to do business. They should act more as entrepreneurs, ready to be flexible to collaborate with the other actors. As for now some inertia has been noticed. What can help is adoption of innovative business models, which have for the basis of value proposition and creation have by-products exchanges. Moreover, what can help is to interact more and participate in exchange the knowledge activities.

Mobilization capacity

Next, the web platform should be created; where the tenants and other interested actors will have an access to the inventories (type / quality / quantity of material). That will help to mobilize the resources, increase the knowledge base and develop the inward looking approach for the companies to meet their needs. It will be also beneficial to expand the scope of the “bank” by inviting other actors outside the park to join the platform. Herewith the first steps for the synergies on the regional level can be made.

Appoint a steering group or person responsible for the identification, development and implementation of the synergies. There should be a specifically appointed personal to advance the synergies and also to support interaction in the park and assist the tenants with their attempts to build the linkages or encourage doing so.

SUR should also employ the recruitment procedure for accommodation of the new tenants. Some tenants, e.g. construction companies, can deliver benefits in terms of synergies either utilizing existing by-products in the park or offering beneficial ones. Since a lot of projects are landing on the table of the commercial team, which is responsible for attracting and recruiting, it can be equipped with some guidance and recommendations to which project give a priority.

Discuss the synergetic opportunities already on the design stage with the new tenants since it is the very stage, when it is possible to make adjustments and enable technically the linkage. However, prior to this the knowledge about the potential synergies and available streams in the park should be much more solid. Furthermore based on the identified counterproductive with the multiple desalination units, QURM should be given a priority to avoid new unnecessary water facilities.

Facing the issue of that slag it became evident that the voice of the single company is not strong enough to change an inert regulatory system. However, if the companies unite in the association and work together to solve the common problems their voice will be weightier. SUR can play such role of the relationship broker and encourage the companies to come together.

Ministry of environment should employ sustainable objectives and targets for Oman as a part of top-down approach, which industries will translate in their own strategies and policies.

Apart from the that economic incentives and regulatory instruments should be in place to help industries perceive the economic advantage in going beyond the compliance, encourage re-use and recycling, apply technologies that as of now are not feasible due to absence of the pressure going from overlooking authorities;

MECA should work out the quality and treatment standards to level a playing field for the industries and get rid of the present ambiguity around the re-use and recycle of the by-products.

Improvement of the enforcement of the current regulations will make the actors to take environmental issues and their management more serious.

It has to be said that potential interventions of the government and the tool box that can be applied to advance industrial symbiosis in Oman is the research question in itself. And it is definitely interesting and useful for Omani context and is an area of future research.

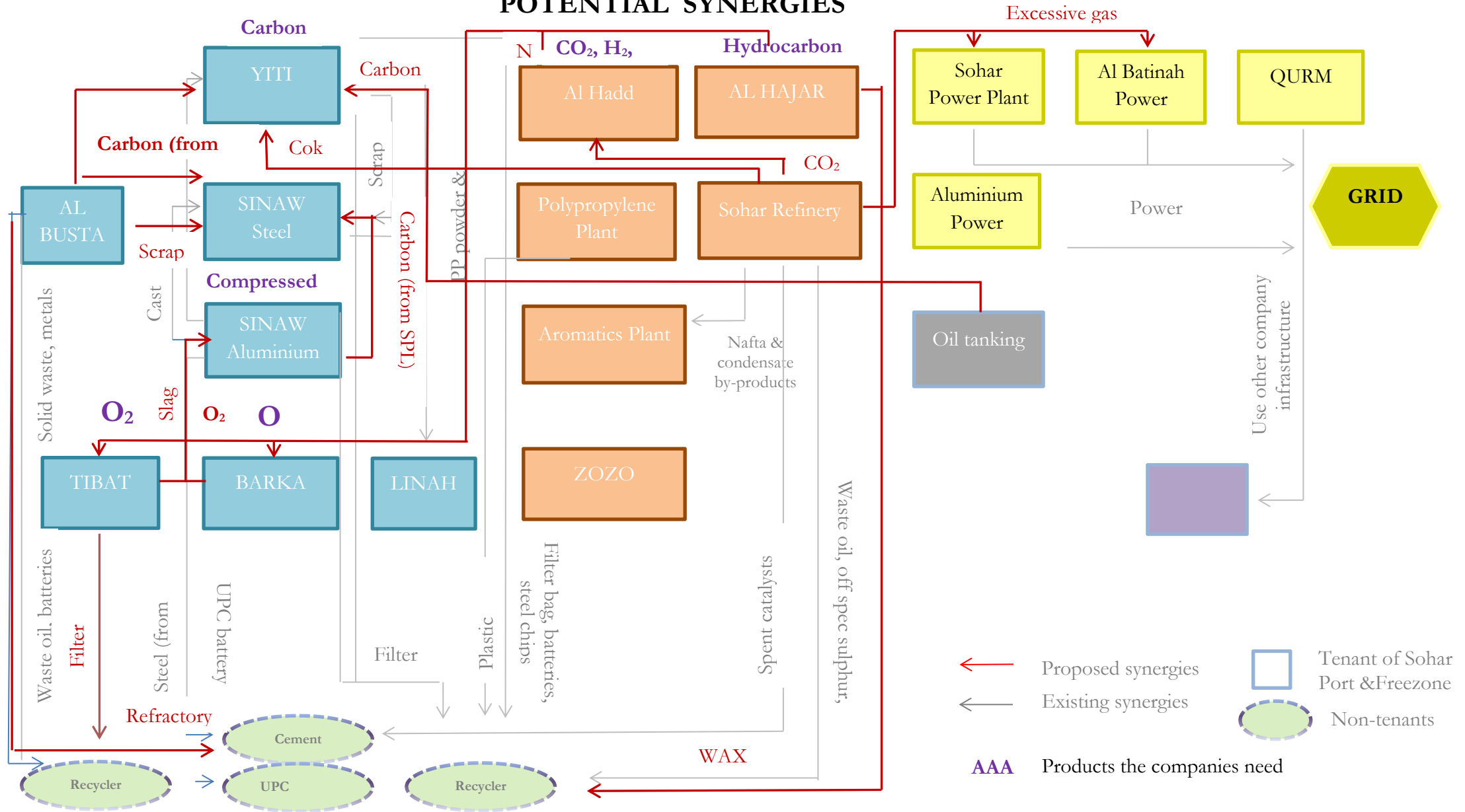
Potentially interesting areas of intervention, the guiding list for coordinators of IS

Interviews and literature review helped to identify a wide array of the synergetic opportunities, which demonstrate the decision-makers and the main actors the potential of IS specifically for SOHAR (figure 10). Unfolding these opportunities might also contribute into mobilization capacity since some synergies are not really hard to implement. However, it needs to be said is has not been sieved through the sieve of “critical success factors”, such as convincing business case, proven technology and stakeholder approval. However, could serve as a good guidance for the future steering group or coordinator of IS in SOHAR. That also could be a future research agenda.

- 1) It has already been mentioned that YITI sees carbon rich material and currently gets it from SINAW Aluminium. Another source could be from AL BUSTAN since they have refractory waste or from Oil Tanking if the agreement on the senior level is reached. Moreover, the coke generated at the oil refinery is worth considering.
- 2) SINAW Steel can also explore the same opportunity as YITI since they have similar Electric Arc Furnace. Thus, their partners could be AL BUSTAN, SINAW Aluminium and Oil Tanking.
- 3) Talking about AL BUSTAN they still should send their scrap metal to SINAW Steel, even though it might very small volumes for the recipient company, but the environmental benefit could be gained by avoiding the transportation emissions.
- 4) Currently AL HAJAR is generating a mix of oxygen and nitrogen, which is not separated as of now. However, two ferro-chrome companies in the park do need O₂ for their operation and neighbouring fertilizing company SUICI needs N.
- 5) As Kalundborg case suggests excessive gas from AL QABIL if any can go to two power companies.
- 6) AL QABIL and Methanol companies generate significant amount of wax, which can be further taken care of by recyclers and make candles or similar products. This practice is implemented in Map Ta Phut park in Thailand and across Taiwan (CECP, 2007).
- 7) As it has been mentioned the researchers suggest the synergy between ferro-chrome companies and foundry industry (Murthy and Rao, 2016), which is in case of Sohar is BARKA, TIBAT and SINAW Aluminium. The by-product that can be exchanged is ferro-chrome slag.
- 8) If relation capacity is improved and MECA would give a green light refractory waste of AL BUSTAN and maybe SINAW Aluminium can be still channelled to Oman Portuguese Cement or other construction companies.
- 9) It has been noticed that for the same type of waste some company did find an application and some not. For example, filter dust, it is being sent back to the process or to the recycler by SINAW Aluminium or YITI. However, TIBAT did not adopt this practice. Another example of this kind is UPC batteries.
- 10) And finally, in the future when certain pressure from MECA comes initiated earlier CO² inventory research might become more relevant. And the biggest CO² emitter will channel its CO² to AL HADD, for which that would be really of value.

Figure 10. Potential synergies

POTENTIAL SYNERGIES



On the graph below the identified hot spots in the park has been schematically laid out (figure 11). There are three major focus areas that deserve attention of management and future research. First of all, it can be seen that there are a lot of companies in the park have their own desalination units, which serve as a source of the process water. It appeared to be this way, first of all, because present water company QURM, came much later than some companies in the park. Secondly, the tenants wanted to secure constant water supply. However, now it appears to be a major source of inefficiency. The companies are spending their own resources (heat, steam) to desalinate the water, whereas QURM's core business is to provide three different types of water. Therefore, the recommendation would be on the stage of design discuss with the future tenants whether they are going to incorporate desalination unit or not. Another possibility is to combine desalination units and share the water between the tenants. That can be also decided earlier on the design stage.

Secondly, a number of heat loss sources were found. First of all, it occurs from cooling down of slag, which exits the furnace at the temperature around 1500°C or more and needs to be chilled to the ambient temperature. Usually it is cooled down by splashing the water. On the one hand, it seems like a good heat source. On the other hand, such shortcoming as low thermal conductivity, easy crystallization and temperature-time discontinuity are generally met in the literature and among practitioners (Rycroft, 2014, Sun et al. 2015). Sun and the colleagues (2015) are saying the slag can be used not only as a heat carrier, but also as catalysts and reactors. Three alternative applications of waste heat from slag are desired as the most promising: decomposition of limestone, reforming of methane and gasification of carbon (Akiyama et al., 2000, Rycroft, 2014, Sun et al. 2015). Furthermore, perhaps there could be a synergy with the AL HAJAR, which produces the syngas, because the slag can be a reactant in the chemical reaction (Sun et al. 2015). Or alternatively the slag can be used for the production of hydrogen (Rycroft, 2014, Purwanto and Akiyama et al., 2006). These found in the literature examples show the potential of the slag especially in face of heavy reliance on fossil fuels and transition to cleaner production.

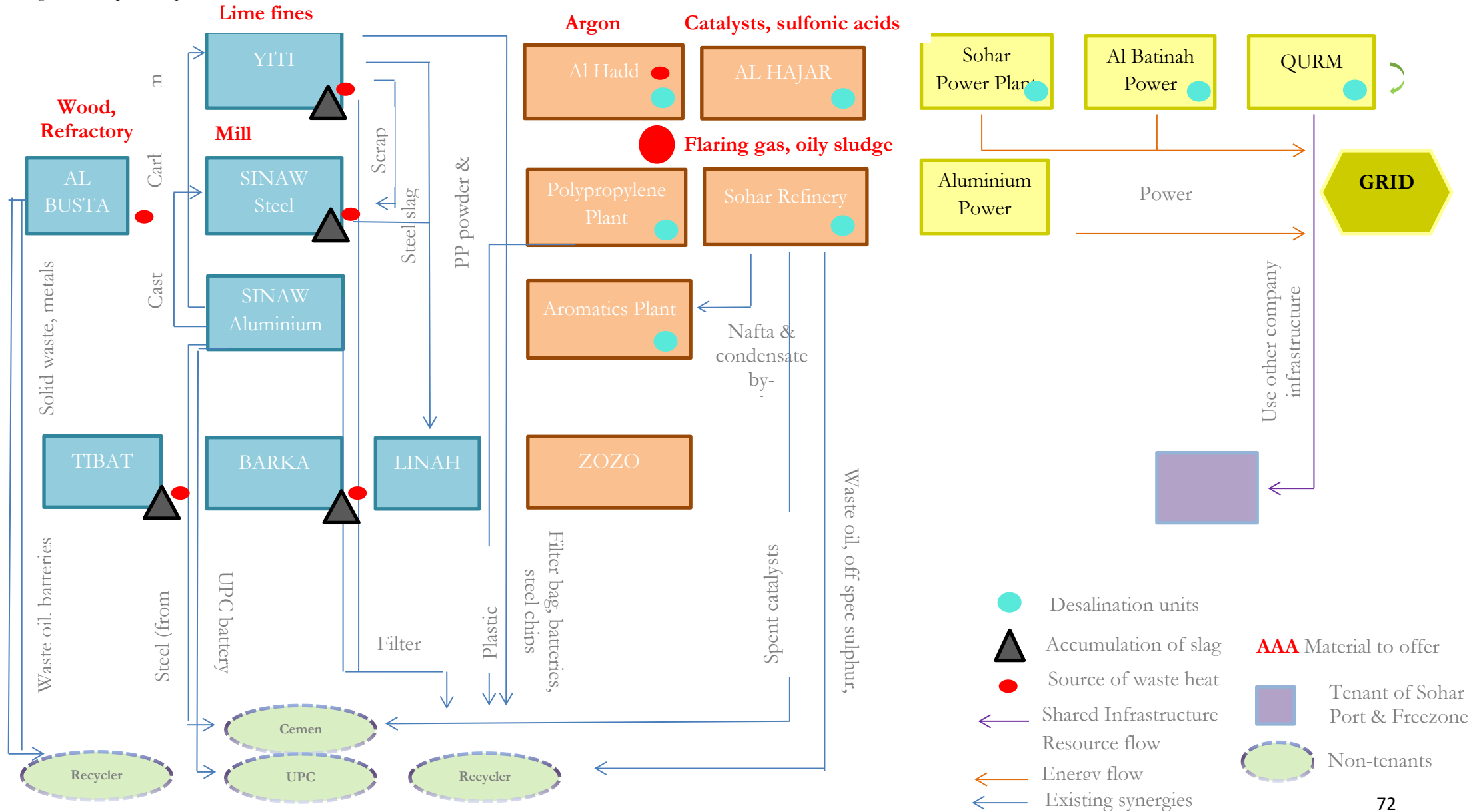
And finally AL QABIL is flaring its gaseous residues at its refinery at rate of 2 tons per hour. Flaring gas is a serious issue due to associated substantial greenhouse emissions and such nuisance as noise (Emam, 2015, Anomohanran 2012, Soltanieh 2016). Perhaps it does not have very valuable content from gas point view as they claim, however it can be a good source of heat (Emam, 2015). However, adequate political and regulatory pressure should be there to encourage AL QABIL to capture the heat and rechannel it (Studer 2012). It can be also used for the co-generation of steam or electricity (Emam, 2015).

Utilization of waste heat

One of the recommendations on how to increase integration in the park and could be to carry out a thorough energy study in park to spot the sources of the heat losses and inefficiencies. And after identification of the sources of the heat loss start utilizing it for different purposes. In fact, it was estimated that between 20% and 50% of the energy consumed worldwide ends up as a waste heat through the conversion inefficacy and transportation in the industrial operations (Liew et al., 2016). However, the waste heat is a valuable source of energy and is widely utilized. One of the way, it can be utilized is to use for the preheating of the materials mainly metals, which are going to the furnaces of the companies from the metal cluster. As of now, none of the companies has adopted pre-heating technology; however it would save a lot of energy, because the material need to reach 1500 °C and more.

Figure 11. Hot spots in the park

HOT SPOTS



Another promising option, which is applied around the world to utilize heat loss is absorption chillers (Lindmark., 2005, Liew et al., 2016). The idea of this technology is to produce space cooling (air or water) using low temperature waste heat (<100°C) (Jaruwongwittaya T, Chen G., Somers et al., 2011). Some authors also explored application of this technology for water desalination (Picinardi, 2011, Chiranjeevi and Srinivas, 2014, Mohan et al., 2016). This technology can significantly reduce the energy bill especially if used for the Air Conditioning purposes (Liew et al., 2016). That should be especially of interest for SUR since the energy bill for the main administrative building covers up to 80% of the AC needs. This technology applied in California, (NBI, 1998), Thailand (Jaruwongwittaya T, Chen G., 2010), testing application in Masdar, UAE (Snieckus, 2011, Siegel 2015) and Qatar for the major football stadium (BBC, 2015). Even in SOHAR park itself one can find an absorption chiller applied at AL QABIL facility.

Utilization of solar energy

Another recommendation is to consider seriously application of solar technology. Solar radiation has among the highest in world potential with the average intensity of 6kWh/m² and 80-90% not cloudy days a year (Alnaser and Alnaser, 2011). The only severe issue is a problem of dust pollution that negatively impact efficiency of the solar panels (Saidan et al., 2016). However, it can be fixed by manual or automatic cleaning systems.

However it is solar energy has much better thermo potential, which is exceeding its electric capacity (Jäger et al., 2014). Thermo energy is valuable from the heat potential perspective and can be already utilized at the temperature of 100°C. Therefore, solar thermal energy can be utilized both the electricity production, but also generate steam, which can be used by the industries. One of the vivid examples is a local oil company, Petroleum Development Oman (PDO). PDO is working upon the project, which will harness the sun's rays to generate steam as a substitution to the gas in enhanced oil recovery (PDO, 2017). This is a good example when fossil industry is back to back and being supported with the renewables. Another potential application of the thermal solar energy is combination with previously mentioned technology of absorption chillers and its application for cooling purposes in the park (Liew et al., 2016).

And finally, as it was also kindly noted by Mr Murudanandam (general manager operations) in AL HADD synergies can be established not only in terms of exchange of the by-products and energy, but also human resources and the premises. According to Mr Murudanandam there is occasionally the need for the certain types of the engineers or other specialized professionals that are usually outsourced. However what is highly probable, Mr Murudanandam notes, is that these human resources are available in the park and can be rotated within it. The problem that might arise is the unwillingness of the tenants to share their know-how and reveal some operational secrets if there are any. This closed and reserved culture has been noticed, for instance, with Oman Formaldehyde Company.

Another mentioned possibility is the use of the same premises as the workshops, for instance. Some of the company's premises are used only occasionally and not to its full capacity, which potentially offers an option of shared use. An obvious difficulty could be the proximity of the premises and convenience for the different workers dispersed around the park.

CONCLUSION

Therefore, influence of the institutional capacity on the development of industrial symbiosis in SOHAR Port & Freezone was examined. A carried out analysis confirms the fact that uptake of industrial symbiosis is equally dependent on the social forces as the technical feasibility. The research showed that institutional capacity is built over the time through repeated interactions, formulation of the common problem, social learning processes, engaging the stakeholders and mobilization of resources. The number of interventions was suggested to the local actors on how to improve institutional capacity and consequently increase the uptake of industrial symbiosis. These interventions aim at improving relation, knowledge and institutional capacity. Among these are to appoint a steering body to coordinate the processes around symbiosis, formalize the interaction platform, uptake more sustainable and innovative business models, employ recruitment procedure for the new tenants in the park and so on.

And another dimension, which was incorporated in this research, is the influential power of the institutional context for the decisions and interests of the actors. Institutional context shapes the opportunities the actors see, including in the area of industrial symbiosis. Local context of SOHAR Port & Freezone can be characterised by a number of strengths and weaknesses. To name a few strengths: already present experience, existing linkages and interactions to build upon, adopted vision to create an integrated industrial park, presence of the important enabling roles such as anchor, champion and to certain extant intermediaries. The weaknesses that can be highlighted are under capacity of the Ministry of Environment, inadequate regulatory support of the resource efficiency measures, absence of market-based instruments pressuring the companies to extract value from the secondary materials, prevailing perception of waste as “waste”, but not a “valuable by-product”.

Therefore, very important driving forces behind implementation of the industrial symbiosis approach were studied in this research. Knowing the leverage points, which this research gives a clue about, will help to boost industrial symbiosis in SOHAR Port & Freezone, embed circularity in operations. That would help to decrease environmental impact of the heavy industries and address relevant sustainability issues.

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