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Strategic Roadmap for Gotland Industrial Symbiosis Park

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Summary

The Roadmap for the Gotland Industrial Symbiosis Park (GISP) is the culmination of the GISP project. IVL was approached by Tillväxt Gotland and Region Gotland with the desire to develop the park based on industrial symbiosis (IS). Industrial symbiosis is a captivating concept that seeks to emulate nature where waste resources or by-products are utilized by other entities.

The aim was therefore to identify the most appropriate development strategy to maximise industrial symbiosis, resource efficient production and the sustainability outcomes of the park. The chosen site is 2 km north of Visby, adjacent to the main airport.

This document summarises the research project and its findings before outlining a suggested Roadmap for GISP's development. It also brings together the research reports conducted during the project (Appendices 1-3) that include a literature review, review of regional strengths and opportunities, and a sustainability assessment of potential scenarios.

Gotland has key strengths which can provide a foundation for a strategic approach including agriculture, tourism, the food and beverage industry, good location and strong potential for renewable energy development and related industries.

Three themes/scenarios were developed to represent differing strategic approaches to GISP development which build on these strengths. These were assessed using life cycle assessment and sustainability assessment.

The sustainability assessment was conducted for three themes (scenarios) that represent three different strategic approaches for the park's development. This highlighted a large variation in potential sustainability outcomes for different approaches. The most appealing is the IS-CE which represents a circular economy (CE) approach, going beyond sustainable production to consider also sustainable consumption. For instance, assessment of this theme demonstrated a potential to offset Greenhouse Gas (GHG) emissions by replacing fossil fuel-based fertilisers with those produced from renewable energy and hydrogen. Although such a company may not locate at GISP, this highlights the potential of encouraging certain companies that can produce sustainable products, to locate at the park.

The Strategic Roadmap consists of three stages: 1. Strategic vision, 2. Implementation and 3. Operation, which are detailed in this report. Developing a strategic vision is designed as a valuable process to ensure the associated stakeholders (Region Gotland, Tillväxt Gotland, planners, companies and developers) understand the strategic sustainability implications of developing GISP based on the different themes and approaches. Therefore, it is a critical component to ensure that the stakeholders develop a clear approach to capitalise on the opportunity to reduce climate impacts, and maximise the sustainability outcomes of GISP.

GISP is a critical opportunity to limit Gotland's impact for generations to come, by focussing on products that offset emissions instead of contributing to them. For example, one of the largest contributors to GHG emissions on Gotland is derived from the agricultural use of fertiliser which adds almost 100,000 tCO₂-eq to Gotland's GHG footprint each year.

The implementation phase consists of: i) establishing a coordinator (to facilitate industrial symbiosis and development), ii) sales and communication (to promote the location and



opportunity), iii) planning, iv) symbiosis identification (processes to help identify synergies between companies, and v) properties and infrastructure (supporting the planning and development). The operation phase consists of coordination to oversee the daily management and a sustainability committee. In addition, symbiosis facilitation, seeks to identify new synergies. Together with a continuous improvement approach (i.e. periodic review of IS and sustainability performance) these elements will help to ensure that sustainability performance is optimised, as products and material flows evolve over time, and different companies leave or locate at GISP.

1 Introduction

The Roadmap for the Gotland Industrial Symbiosis Park (GISP) is the culmination of the 2-year GISP research project conducted between 2020 and 2022. It also brings together the research reports conducted during the project (Appendices 1-3). The project's aim was to identify the most appropriate development strategy to maximise industrial symbiosis, resource efficient production and the sustainability outcomes of the park. The chosen site is 2 km north of Visby, adjacent to the main airport.

IVL was approached by Tillväxt Gotland and Region Gotland with the desire to develop the park based on industrial symbiosis (IS). Industrial symbiosis is a captivating concept that seeks to emulate nature where waste resources or by-products are utilized by other entities.

However, developing this within an greenfield site is an enormous challenge. Most of the foremost examples of industrial symbiosis (e.g. Kalundborg, Denmark and Kwinana, Western Australia) attribute their success to existing companies developing collaborative relationships. Much of the literature points to limited success when attempting to develop industrial symbiosis on a greenfield site. This is mainly because companies locate on industrial parks on an ad-hoc basis. Therefore, the project team developed a comprehensive methodology to help develop a potential strategy and roadmap for development.

This document summarises the research project and its findings before outlining a suggested Roadmap for GISP's development. It is structured as follows: section 2 briefly presents the GISP project and its findings before section 3 presents the Roadmap. Further detailed information can be found in the individual reports that are attached as appendices 1-3.

2 GISP Research Project

The project conducted the following main tasks:

1. **Literature review** – a comprehensive review of industrial symbiosis examples, literature and related topics.
2. **Regional strengths and opportunities review** – which involved a strengths, weaknesses, opportunities and threats (SWOT) review of Gotland.
3. **Assessment of potential development themes** - sustainability assessment of development scenarios using a combination of life cycle assessment and semi-qualitative (qualitative analysis and scoring) using a set of 15 socio-economic and strategic indicators.

These three are presented briefly in the following sections. In addition, the project performed resource flow analysis of local industry and agriculture as well as a scenario workshop, which explored possible scenarios using the SymbioCity methodology¹.

2.1 Literature review

There is an extensive volume of research and popular literature on industrial symbiosis and the related field of industrial ecology that stretches back to the early 1990's. In addition to reviewing the appropriate industrial symbiosis literature, the review covered a range of related topics including:

- Development of an IS park – reviewing industrial clusters, development processes, strategies and business models.
- Development of IS synergies – reviewing the identification of IS synergies, lessons for success, the role of facilitators and business models for synergies.
- Implications of IS for the circular economy, socio-economic outcomes, and implications for industrial development.

The literature review concluded that the steps to develop an IS park can be categorized into 4 parts:

1. Securing commitment of stakeholders and creating common vision for the park.
2. Technical diagnostic to identify synergies followed by financial assessments.
3. Creating detailed implementation and business plans and strengthening organisational capacity.
4. Developing a framework for reporting and monitoring.

Three development strategies were identified as suitable for the development of Gotland IS Park:

- i. Local industries in a multi-anchor tenant model.
- ii. Focus on water as the key environmental issue.
- iii. Focus on energy as the key resource issue.

¹ See for example: <https://symbiocity.org/wp-content/uploads/2020/01/SC-publication-2.0-Summary.pdf>

It may also be possible to combine two or all of these strategies together in the park, depending on the interest from companies and other stakeholders.

Different tools for identification of synergies were reviewed, such a matrix of by-products and potential receivers or the use of data collection and matching software. Trust between companies and a willingness for collaboration are critical factors in the development of synergies. Support from the regional bodies can also play a key role and could come in the form of financial, informational, capacity building forms, or by allowing a flexibility in the existing regulations. Financial viability of the IS synergies has been identified as a key consideration and is important specially for the long-term sustenance of a network.

2.2 Regional strengths and opportunities.

Research suggests that success in industrial regional development is most likely when building on regional strengths and the existing skills capacity (e.g. Porter, 2000). Therefore, the regional strengths and opportunities work sought to identify Gotland's regional strengths and capacities and investigate current challenges and threats. The analysis consisted of three parts: scoping and background, the strategic SWOT-analysis and platform review including stakeholder interviews.

Gotland has about 60 000 inhabitants and is the largest island in the Baltic Sea. Public services account for the single biggest employer, primarily Region Gotland. Tourism and the industry provide most of the revenue on the island according to statistics from Statistics Sweden (SCB).

The SWOT analysis identified the following strengths on Gotland:

- **Established business sectors** – agriculture, tourism, food and beverage as well as mineral processing are key industries that provide a solid foundation, with skills and employment capacity.
- **Natural endowments** – renewable energy, including wind, wave power and sun. There are further opportunities including solar thermal.
- **Collaboration** – there is a well-established history of collaboration on the island, including industrial networks. For example, there are existing synergies involving gas and energy. This has the potential to be extended and there are opportunities in the vicinity of the industrial symbiosis park for collaboration and exchanges of valuable resources.

The key challenges identified in the analysis are the sustainable supply of water and electricity, logistical challenges and a lack of human resources and competence for some business sectors. A recommendation is to aim for a holistic approach when developing an industrial symbiosis and circular economy on Gotland. One important area is the development of a sustainable tourist strategy that is aligned with the strategic supply of energy and water.

2.3 Assessment of themes

2.3.1 Methodology

To assess potential strategic development options and approaches for GISP, we developed three “themes” which represent different potential development approaches. This approach is therefore intended as a method to understand potential consequences and provide scenarios on which future discussions can utilise to aid the optimum development of GISP. These differ in terms of industry sectors, required skills, resource use and potential resource connections both internally and with the island as a whole. The three themes are summarised in Table 1:

1. **Food, Tourism and Agriculture (FAT)** – is a scenario that represents an approach that builds on existing strengths and skills capacity of the island. This theme therefore focuses on a symbiotic network with local food and beverages, brewery, bakery, shops and restaurants aimed at connoisseurs and tourism.
2. **Small and Medium-sized Enterprises (SME)** – represents a scenario that follows a traditional commercial focus where SME’s are encouraged to locate to fill land on a willing to pay rent basis. The modelled theme includes a park consisting of a sign’s & graphics producer, an office and conference centre, an electric motorbike producer, wool production, textiles, utility company and a facility for reuse of demolition by-products. A heat network exists in the park to supply and reuse waste heat.
3. **Industrial Symbiosis and Circular Economy integration theme (IS-CE)** – represents a scenario where industries are encouraged to locate at GISP that form supply/customer or industrial symbiosis with existing local companies and entities; and/or they support the development of a circular economy on the island. The example for this theme centres around the utilisation of excess renewable energy to produce hydrogen and green ammonia. The green ammonia is used in local agriculture in place of fossil-based fertiliser. Other entities in the theme included a sign’s producer, an office and a conference centre, and a facility for reuse of demolition by-products.

A strategic sustainability assessment of the scenarios was performed using a combination of life cycle assessment and strategic socio-economic assessment. The latter consisted of a semi-qualitative analysis combined with a scoring (based on likeliness of occurrence and strength of impact) using a set of 15 socio-economic and strategic indicators.

Table 1: Themes and related strategic development approaches that were assessed

Theme	Represents	Strategic approach
1) FAT	Small scale/ bio-based/food production and tourism	Integrated bio-based IS approach Build on regional strengths
2) SME	Collection of SME’s and an office	Get tenants at the park. Foster IS if possible.
3) IS-CE	Sustainable products and consumption.Circular economy	Integrated IS internally and externally. Sustainable products that replace impactful products used on the island.

Each theme was modelled based on a theoretical configuration of companies, using actual data (e.g on quantities of resources consumed and products) from real examples and databases. Potential

symbiosis between the companies were identified and assessed using life cycle assessment and the indicator framework. An example of the types of interaction and companies modelled is shown in Figure 1, which shows the IS-CE theme (see Appendix 3 for further details).

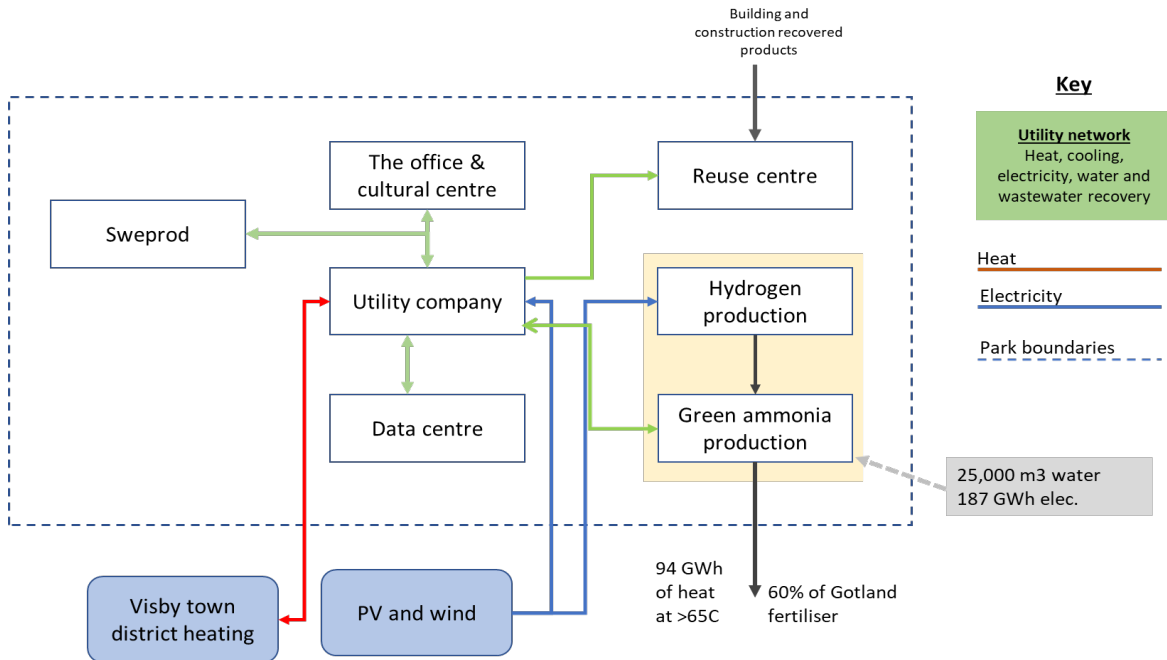


Figure 1: The modelled entities, and symbiotic and circular economy interactions in the IS-CE theme

2.3.2 Theme assessment results

A comparison of the GHG emissions of each theme (for a years' operation and production) is shown in Figure 2. It shows that the SME theme has the highest GHG emissions, the FAT minimal emissions, whilst the IS-CE theme provides negative emissions. However, the difference in emissions between the FAT and the SME is less if measured per MSEK. This shows that they are quite similar if considered on an economic basis.

The negative emissions of the IS-CE are due to the offsets (or credits) provided by the replacement of 60% of the current fossil fuel-based fertilisers (approximately 30,000 tonnes of fertiliser per year are imported to Gotland). This results in a credit of 30 Ktonnes CO₂-eq from the production of green ammonia.

A comparison of the GHG emissions with resource depletion impacts and water resource depletion impacts is shown in Figure 3. It shows that the SME theme is the worst performer apart from the water resource depletion. This is because of the water required for green ammonia production. However, this impact could be mitigated if desalinated water from the Baltic Sea or collected rainwater were used as a water source.

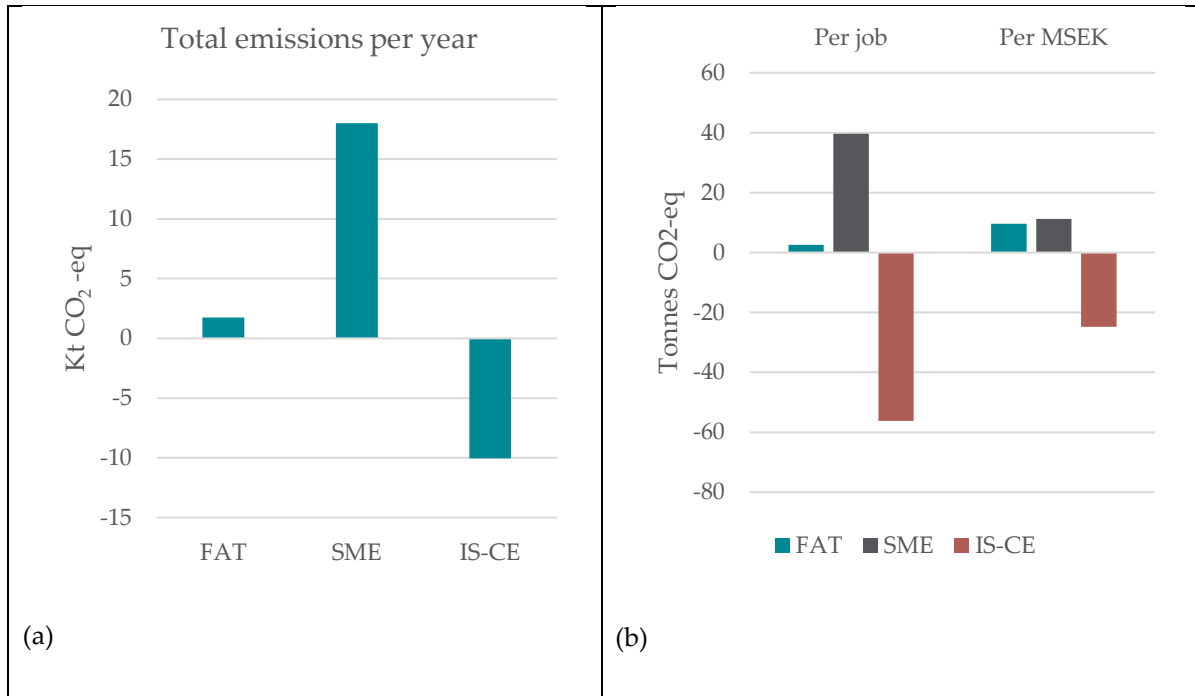


Figure 2: Climate change for operation of the three GISP themes per year (a) Total CO₂-eq emissions per year, (b) GHG emissions/year/job and GHG emissions/year/MSEK.

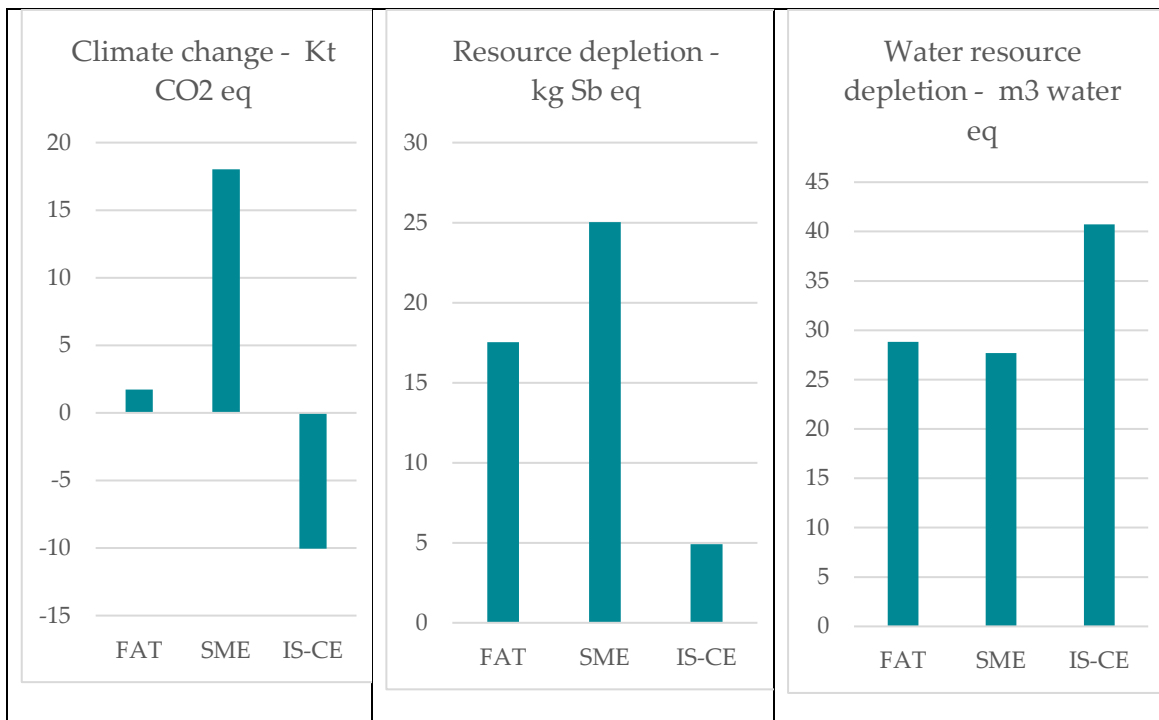


Figure 3: Comparison of the three themes for three impact categories

Figure 4 presents the scoring for the results of the qualitative sustainability scoring. The IS-CE clearly scores best with 27 (out of a maximum of 30), followed by FAT with 18 and SME with 13. All themes would therefore be expected to provide benefits but IS-CE is noticeably better because it scores well across all sustainability indicators. It has the potential for strong integration with the

island resources and industries and focuses on sustainable products (that aid sustainable and circular consumption) that can replace currently high impacting products (i.e. fossil based fertilisers).

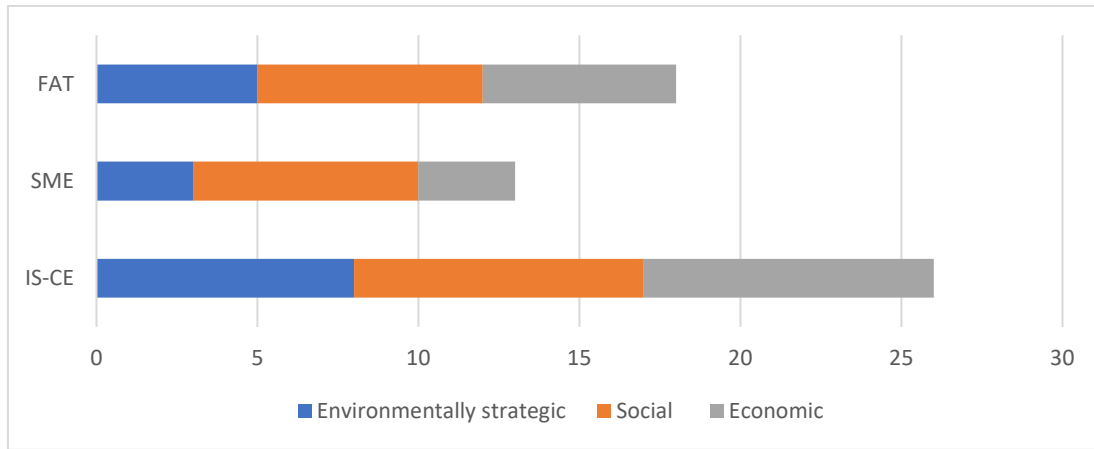


Figure 4: Scoring of the themes for the strategic sustainability indicators

3 Strategic Roadmap

3.1 Understanding the strategic implications

In this section we propose an outline and suggestions for a strategic roadmap for the development of GISP. The assessment of the themes demonstrated the diverse sustainability impacts and outcomes for the different approaches.

It is important to understand that the themes are intended to represent possible strategic approaches for GISP. In Table 2 we outline what the themes represent and the pros and cons of each theme. FAT represents a focus of building on regional strengths, SME a focus on linear economic production, and IS-CE on producing products that can function within the circular economy. The latter means that it goes beyond “sustainable production” where the focus is on limiting emissions and impact during production only – to considering the whole lifecycle of the products from materials, production through to the products use and recycling. This represents a strategic choice of purposely selecting and encouraging certain companies or company types, to locate at the park.

Table 2: Pros and cons of different strategic development approaches for GISP for industry types

Strategic approach		Pros	Cons
1) FAT	Small scale bio-based. Building on regional strengths	<ul style="list-style-type: none"> ✓ Utilises, and strengthens, existing skills capacity ✓ Many synergies and bio-based materials 	<ul style="list-style-type: none"> ➤ Low growth potential
2) SME	Getting tenants at the park Production focussed	<ul style="list-style-type: none"> ✓ Potential economic gains/regional taxes ✓ Potential for utility synergies 	<ul style="list-style-type: none"> ➤ Long term risks ➤ Limited amount of synergies possible
3) IS-CE	Sustainable production & consumption (products for the circular economy). Selective companies	<ul style="list-style-type: none"> ✓ Long term focus ✓ Regenerative (minimal societal impact) ✓ Strengthen economy ✓ High growth potential 	<ul style="list-style-type: none"> ➤ Complex ➤ Time to identify and attract appropriate companies ➤ Requires strong, committed leadership

Developers of a traditional industrial park (SME theme) typically prepare the park and lots by providing the necessary infrastructure. It is the easiest to implement but has limited potential for reducing environmental impact of production and consumption. Some mitigation can occur by identifying symbiosis such as by-product or energy exchanges.

However, in contrast the IS-CE theme aims to encourage selective companies to the park with the specific purpose of enabling IS exchanges and manufacturing products that either mitigate environmental impacts (e.g. replacing highly polluting products) or are designed for the circular economy.

3.2 Alignment with Gotland's Vision

Carbon neutrality is often misunderstood because accounting calculations do not often include consumption-based GHG emissions (also known as Scope 3 or supply chain) – which are often the largest share.

The vision of Gotland for 2040 is described in the regional development strategy “*Our Gotland 2040*” and has three main goals, that “Gotland is a”:

1. Safe and inclusive society with good quality of life for all.
2. Role model in the energy and climate transition.
3. Innovative growth region with development capacity.

These are all relevant for the development of GISP and they are critical considerations for the GISP strategy, as GISP can have a strong influence on them.

In *Our Gotland 2040* the priorities for achieving the energy climate change goal are to “Be at the forefront of the climate and energy transition”, with sub-goals stated as:

- i. Reduce climate impact throughout society.
- ii. Transition to a sustainable and robust energy system based on renewable energy.
- iii. Increase energy efficiency and reduce energy consumption.
- iv. Encourage knowledge-sharing and participation in the climate and energy transition.
- v. Adapting society to a changing climate.

The first of these sub-goals presents a timely and critical opportunity for GISP. Reducing climate impact throughout society is not only about renewable energy but must also address the products and resources that are consumed. Research clearly shows that in Sweden much of the carbon footprint occurs *indirectly* in other countries, where products are produced. Figure 5 shows that over 60% of Swedish GHG emissions occur upstream in other countries, in the early stages of the value chain such as material extraction and production.

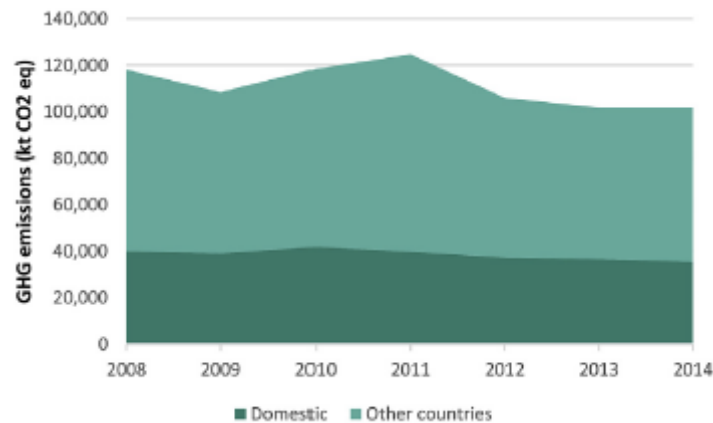


Figure 5: Swedish GHG emissions, domestic versus external for 2008 – 2014 (Source: Palm et al. 2020).

3.2.1 GISP a critical opportunity

GISP represents an opportunity for sustainable production and consumption on Gotland, by providing products that mitigate carbon emissions and function within the circular economy. For example, on Gotland, one of the largest footprints is derived from the agricultural use of fertiliser which adds almost 100,000 tCO₂-eq to Gotland's GHG footprint each year².

This emphasises the opportunity provided by the IS-CE theme, where fossil fuel-based fertilisers are replaced by those based on excess (off-peak) renewable energy and green ammonia. This provides an opportunity to:

1. Lower the production and consumption impacts (including the avoidance of importing fertilisers).
2. Market such products as carbon neutral or providing avoided emissions (Scope 4).

Other similar opportunities exist and should be investigated and considered such as production of circular products or those that help to avoid impacts such as electric motorbikes.

Since there are significant plans and opportunities for Gotland to develop offshore wind power, substantial prospects are emerging to capitalise on excess renewable energy and hydrogen derivatives. In addition, support services for renewable energy may be required, such as remanufacturing and repair of wind turbines and components.

3.3 Roadmap outline

We propose the following three main phases for the roadmap, which are presented in Figure 6:

- **Phase 1) Vision and strategy development:** to define a vision and set of goals that support the development of GISP as a central tenant of a circular and low impact Gotland. In addition, develop a strategic approach of how the vision can be achieved.

² Based on 26,000 tonnes of fertiliser and using a footprint of 3.5 t CO₂-eq per tonne of fertiliser.

- **Phase 2) Implementation:** to implement the vision and strategy, marketing to secure companies, planning and construction, and identification of symbiotic opportunities.
- **Phase 3) Operation:** to support the daily operation of GISP and facilitate environmental improvements and symbiosis.

These were derived following discussions with Region Gotland and Tillväxt Gotland regarding the main elements required for the implementation. The strategic vision was then added as a critical part to ensure that the stakeholders develop a clear approach to maximise sustainability outcomes. In addition, the operation phase is later required to ensure continuous support and development of IS opportunities, that may emerge with new products and new companies.

The three phases are presented and elaborated in the following sections.

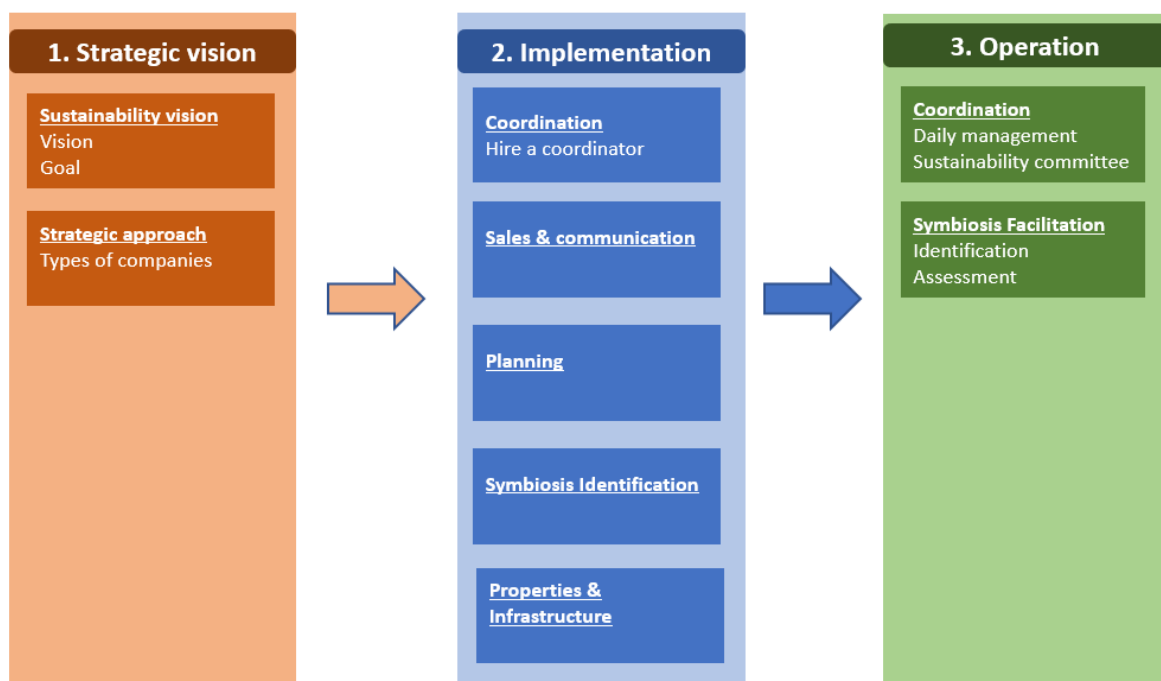


Figure 6: Outline of the Roadmap

3.3.1 Phase 1: Vision and strategy development

This phase contains two main parts: the vision and the strategy of how to achieve the vision, which are outlined below.

3.3.1.1 Sustainability vision

The process of developing a vision and goals for GISP has already begun with the GISP project, but these should be revisited to ensure that they align with the developers, Tillväxt Gotland and Region Gotland.

Crucially, the vision and goals should consider three parts: 1) internal to the park and 2) external linkages, 3) types of products and services produced.

The Symbio City workshop that was conducted within the project identified the following goals for GISP:

1. Creation of job opportunities and maintaining sufficient competence – developing and meeting the required skills capacity.
2. Zero waste – utilising resources so that waste becomes a resource.
3. Integrated utility and technical systems – energy, water/wastewater, logistics.
4. Collaboration and connections – diversity of size, companies and industries; and connections to existing businesses (e.g. Science Park, Blått centrum, circular companies). This includes cooperation around the Baltic Sea area.
5. Innovative companies - high degree of innovation, turning challenges into opportunities.
6. Building on regional strengths – e.g. food industry, tourism industry and the energy transition.

Other questions to consider in the vision and goals include:

- a) How does the park link to Gotland in terms of resource flows and products?
- b) Does it align with the regional development strategy, including the three goals of “Our Gotland 2040”?
- c) What is the ambition level for the degree of sustainable production and consumption:
 - i. Standard approach.
 - ii. Industrial symbiosis internal / external – sustainable production.
 - iii. Industrial symbiosis and the circular economy – promoting sustainable production and consumption.

Finally, the vision and goals should be mapped to specific indicators that can track progress to ensure the vision and goals are achieved. These can include resource-based indicators such as material mass per economic output, water use and recycling; as well as energy based such as share of renewable energy, energy recovery and greenhouse gas emissions.

3.3.1.2 Strategic Development Approach

The latter question above is of central importance for the strategic approach, which includes the level of planning involved to recruit companies, the marketing needs, and the political elevation required (i.e. what level of government should be involved in identifying and attracting companies).

The strategic approach should consider the following:

- How to achieve the goals and vision.
- Industries and size of companies desired.
- Types of companies available and possible to contact, which determines who at Tillväxt/Region Gotland should be involved in marketing and how long this process should take.
- Length of time available to identify, contact and convince potential companies to locate.
- Incentives for companies.
- All elements of the implementation phase.

3.3.2 Phase 2: Implementation

The following five parts of the implementation are briefly summarised below:

1. **Coordination** - a coordinator should be selected to oversee the coordination of the parks development and decide how the operation phase of the park will be performed. A crucial consideration is the ongoing coordination and management of the park and company interactions (see below)
2. **Sales and communication** – marketing of the concept and vision for GISP to attract and identify companies. This will depend on the strategic approach and the use of tools and incentives to encourage location of companies.
3. **Planning** – this concerns the ongoing planning of the site, layout and required infrastructure.
4. **Symbiosis identification** – once the companies are identified and have agreed to locate at GISP then a full assessment of potential symbiosis should be made. This will typically cover:
 - a. Utility symbiosis involving the provision energy
 - b. Resource symbiosis – involving linkages between the companies in the park and with the surrounding areas, including for example district heating network of Visby.
5. **Properties and infrastructure** – include the construction of the properties and company facilities and the required infrastructure.

3.3.3 Phase 3: Operation

As stated above, it is important to prepare for the operation of the park which includes the ongoing coordination, management, and company interactions. One of the main aims is to maintain existing symbiotic exchanges and investigate and foster new exchanges on an ongoing basis.

Environmental improvement should be a continuous process. For example, there are likely to be continual changes to companies, materials used, as well as waste resources or by-products created. In order to promote collaboration regular meetings e.g. through an sustainability committee may be necessary. The sustainability committee's purpose is also to set targets on sustainability and develop joint projects to continually enhance the sustainability of GISP.

In addition, a park coordinator could have a role in helping the companies review the types of agreements available for different symbiotic exchanges and negotiate how benefits can be divided.

4 Concluding remarks

The GISP research project demonstrated the viability and benefits of developing GISP based on industrial symbiosis and the circular economy. Gotland has key strengths including agriculture, tourism, the food and beverage industry, a good location and strong potential for renewable energy development and related industries (e.g. production of hydrogen and derivatives).

A sustainability assessment was conducted for three themes that represent three different strategic approaches for the park's development. This highlighted a large variation in potential sustainability outcomes for different approaches. The most appealing is the IS-CE which represents a circular economy approach, going beyond sustainable production to consider also sustainable

consumption. For instance, assessment of this theme demonstrated a potential to offset GHG emissions by replacing fossil fuel-based fertilisers with those produced from renewable energy and hydrogen. Although such a company may not locate at GISP, this highlights the potential of encouraging certain companies that can produce sustainable products, to locate at the park.

The Roadmap is based on three phases: vision and strategy development, implementation and operation. A critical task to perform the symbiosis identification and assessment once an initial set of companies have been identified. In addition, a continuous improvement approach (i.e. periodic review of IS and sustainability performance) will help ensure that sustainability performance is optimised, as products and material flows evolve over time, and different companies come and go.

5 References

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Porter, M. E. (2000). Location, Competition, and Economic Development: Local Clusters in a Global Economy. *Economic Development Quarterly*, 14(1), 15-34.
<https://doi.org/10.1177/089124240001400105>

6 Appendices

The following reports are attached as Appendices and can also be downloaded separately from the IVL website.

- Appendix 1: Development of Eco-Industrial Parks and Industrial Symbiosis Networks: A Review:
<https://ivl.diva-portal.org/smash/get/diva2:1749864/ATTACHMENT01.pdf>
- Appendix 2: Regional Strengths and Opportunities:
<https://ivl.diva-portal.org/smash/get/diva2:1749864/ATTACHMENT02.pdf>
- Appendix 3: Report on the Identification and Assessment of Options for GISP Development:
<https://ivl.diva-portal.org/smash/get/diva2:1749864/ATTACHMENT03.pdf>



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