Overall strategy and recommendations to foster a wide application of industrial symbiosis at local, regional and European level

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SCALING EUROPEAN RESOURCES WITH INDUSTRIAL SYMBIOSIS

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Authors

Name: Dr Doroteya Vladimirova

Organisation: University of Cambridge

Name: João Azevedo, Marco Estrela, Rui Dias

Organisation: ISQ

Name: Jean-Baptiste Quintana

Organisation: Strane Innovation

Name: Prof Steve Evans

Organisation: University of Cambridge

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Doroteya Vladimirova	University of Cambridge

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Abstract

The objective of this report is to provide a coherent, comprehensive and internally consistent description of plausible futures scenarios with respect to Industrial Symbiosis based on the SCALER research to date. We derive recommendations for different stakeholders to help realise the benefits from the application of industrial symbiosis at scale.

We adopted a Scenario Thinking approach to develop a scenario planning methodology geared towards deriving future scenarios specifically for industrial symbiosis. The value of the scenario planning methodology lies primarily in developing skills for improving knowledge, consistency and robustness of coherent long-term scenario definition.

Taking into consideration the findings and the results from WP2 and WP3 and in consultation with the Advisory Board of the SCALER project, we developed scenarios that support the SCALER vision and overall strategy. These scenarios outline possible future landscapes derived from the research conducted by the SCALER consortium in the previous 24 months. Based on the integration of multiple best-case scenarios, we propose a future way forward to promote a wider application of industrial symbiosis at European level.

Inherent to the strategy definition is the consideration of the different stakeholders at European, national, regional and local level. These recommendations aim to facilitate the implementation of the SCALER vision in mid-term and long-term perspectives in the context of the various focusing issues of the project, including non-technological and technological barriers, investment needs, policy making and standardization, research and innovation activities, resource matching and synergies.

This deliverable D4.1 builds upon the research findings in previous deliverables published in the SCALER project. More precisely, the SCALER scenario planning approach and high level vision presented in this report are grounded in the work carried out for D2.1 *Lessons learnt and best practices for enhancing industrial symbiosis in the process industry*; D2.2 *The role of intermediaries and enabling technologies for identification and implementation of industrial symbiosis*; D2.3 *How to create incentives for industrial symbiosis while preventing and mitigating implementation risks;* D2.4 *Pathways to increase industrial symbiosis including tools and methods for stakeholders;* D3.2 *Technology database for synergy setups*; D3.3 *Synergies environmental impact assessment;* D3.4 *Synergies socio-economic impact assessment;* and D3.5 *Quantified potential of industrial symbiosis in Europe*.

This report is the pinnacle of a two-year long journey of deep investigation, discovery and navigation through the complexities of industrial symbiosis.

1. Introduction

The aim of this study is to devise future scenarios for the scale-up of industrial symbiosis. The scenarios lay the foundation for and inform a high level vision and an aspired future for industrial symbiosis. The objective of this report is to develop an evidence-based SCALER vision and propose a strategy and recommendations for deployment. This report D4.1, provides a coherent, comprehensive and internally consistent description of plausible futures scenarios with respect to Industrial Symbiosis. We adopted a Scenario Thinking approach to develop and customize a scenario planning methodology geared towards deriving future scenarios for industrial symbiosis in particular.

We developed the Scaler scenario planning methodology in the context of industrial symbiosis in several steps. First, from our prior research on this project, we identified a set of critical uncertainties in regard to the implementation of industrial symbiosis, which defined the boundaries of enquiry for the scenarios. Second, we built multiple scenarios that underpin the overall vision development (16 scenarios altogether). We proposed best case and worst case scenarios. The summation of the best case scenarios provided the foundation for the SCALER vision and informed the recommendations to the various stakeholders as elaborated in this research.

In summary, this deliverable has been directly informed by the developments made by the Scaler project partners in the previous seven deliverables from WP2 and WP3. Taking into consideration the findings and the results from WP2 and WP3 of the project, the scenarios developed in this deliverable D4.1 support the SCALER high level vision. Based on the integration of multiple best-case scenarios, we propose a future way forward - the SCALER vision - to promote a wider application of industrial symbiosis at European level.

Inherent to the strategy definition has been the consideration of the different stakeholders at European, national, regional and local level. These recommendations aim to facilitate the implementation of the SCALER vision in the mid-term (~5 years) and long-term (~10 years).

This report, Deliverable 4.1, addresses Task 4.1 *Deployment of SCALER vision and generation of overall strategy and recommendations for industrial symbiosis* in Work Package 4. This work is part of a wider study, which seeks to boost the application of IS in the process industry by considering non-technical and technical best practices, enabling technologies, resource matching and synergies, key intermediaries and facilitating tools and methods, and policy making and standardization.

2. Scenario thinking approach

Contemporary scenario based planning was pioneered by Pierre Wack in Royal Dutch/Shell in the late 1960s and early 1970s in an attempt to forecast the future of the U.S. oil industry amidst several oil crises. The two seminal papers that emerged from this work - Wack (1985a) and Wack (1985b) - were published in the Harvard Business Review and outlined the fundamental principles of scenario planning. The problem, however, was that they offered very little practical advice, and readers had to connect the dots on their own. This was indeed the case until the "Art of the Long View: Planning for the Future in an Uncertain World" was published by Peter Schwartz (1991,1997). The famous scenario planning 2x2 matrix approach for developing foresight could be seen on the back of the book (Figure 1). Schwartz (1991) suggests that the significance of scenario thinking lies in its ability to overcome thinking limitations by developing multiple scenarios for the future. He suggests that broadly scenarios are "stories", "maps of the future", "mental maps", "narratives", "indicators" or "tools"; and that scenario planning is an art rather than science, whereby "critical uncertainties" are a core component and represent the factors that are most likely to shape future directions (Schwartz, 1991).

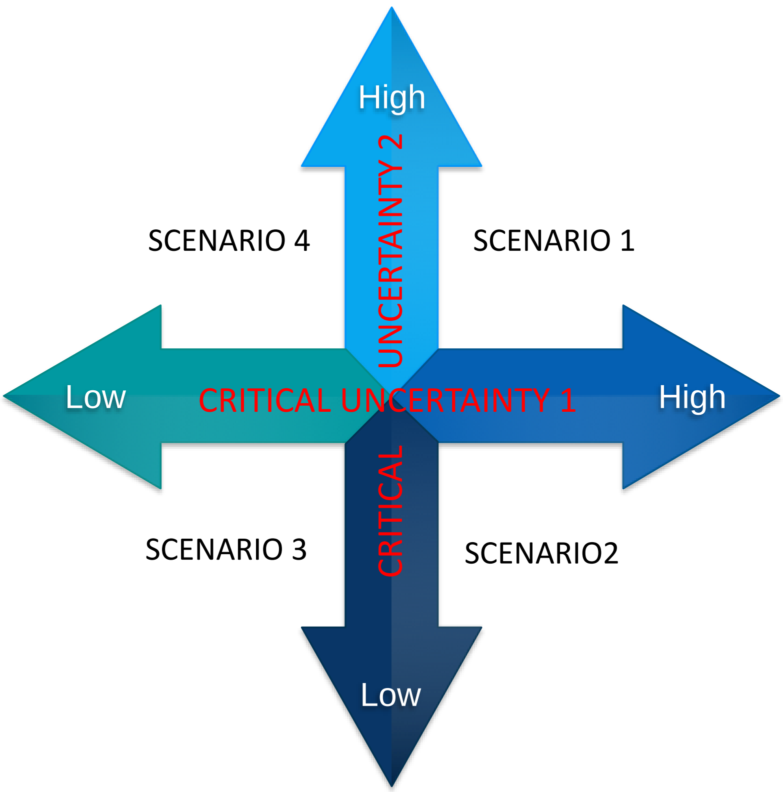

Figure 1 - Scenario Planning 2x2 Matrix

(Schwartz, 1991)

2.1 Scenario planning methodology for industrial symbiosis

In the context of industrial symbiosis, and grounded in the research conducted for SCALER to date, we broadly followed and adjusted for the IS context, the scenario planning methodology for constructing industry scenarios proposed by Porter (2004) in Chapter 13 of his book "Competitive advantage: creating and sustaining superior performance."

We developed the following process to construct 16 future scenarios for industrial symbiosis (Figure 3):

1. Identify evidence-based critical uncertainties based on completed SCALER research.

    - X = Critical uncertainty 1
    - Y = Critical uncertainty 2

2. Identify what "Low" and "High" mean for each critical uncertainty.

    - Critical uncertainty 1:
        - ⇒ X Low
        - ⇒ X High

    - Critical uncertainty 2:
        - ⇒ Y Low
        - ⇒ Y High

3. Map the critical uncertainties on the X and Y axes of the scenario planning 2X2 matrix.

4. Develop 4 scenarios in each quadrant using the Key Industrial Symbiosis Actors (Figure 2) as a point of reference to construct the plots.

5. Entitle each scenario to communicate the key idea/story/plot behind it and identify the best and the worst case scenarios.

6. Validate scenarios with external experts.

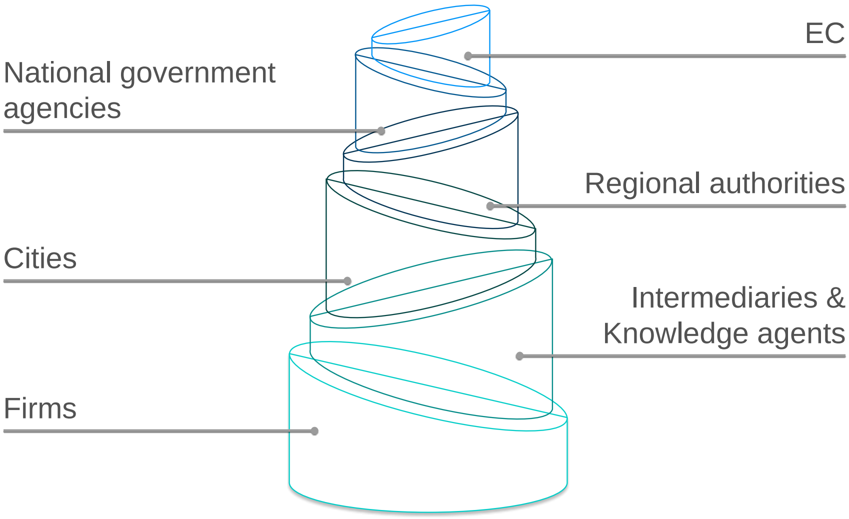

Figure 2 - Key Industrial Symbiosis Actors

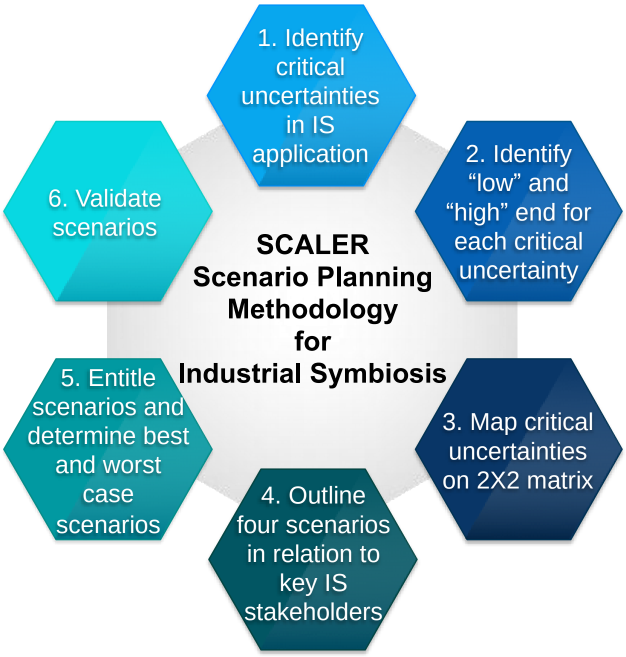

Figure 3 - SCALER Scenario Planning Methodology for Industrial Symbiosis

3. Future scenarios for industrial symbiosis scale-up

The construction of the 16 scenarios within the scope of 8 critical uncertainties presented in this chapter was a collaborative endeavour among the project partners. The scenarios were also validated with the SCALER Advisory Board Members, representing active industrial symbiosis industrialists and intermediaries. It is important to note that all scenarios have undergone multiple rounds of iterations, refinements and validation, and only the final constructs are shown in this report. **It is also important to be reminded that such scenarios are not predictions or directives for the future but offer views of possible futures informed by prior research.**

3.1 Investment and Intermediaries

The first two critical uncertainties that we identified from our prior research (published in deliverables D2.1 and D2.2) relate to the availability and access to funding and investment, and the involvement of intermediaries. We followed the outlined methodology in Figure 3 to develop four scenarios against the parameters for each quadrant of the scenario planning matrix.

Critical uncertainty 1: INVESTMENT

- Low = MARKET DRIVEN PRIVATE INVESTMENT
- High = PUBLIC INVESTMENT

Critical uncertainty 2: INTERMEDIARY ENGAGEMENT

- Low = NO INTERMEDIARY INVOLVEMENT
- High = ENGAGED INTERMEDIARY

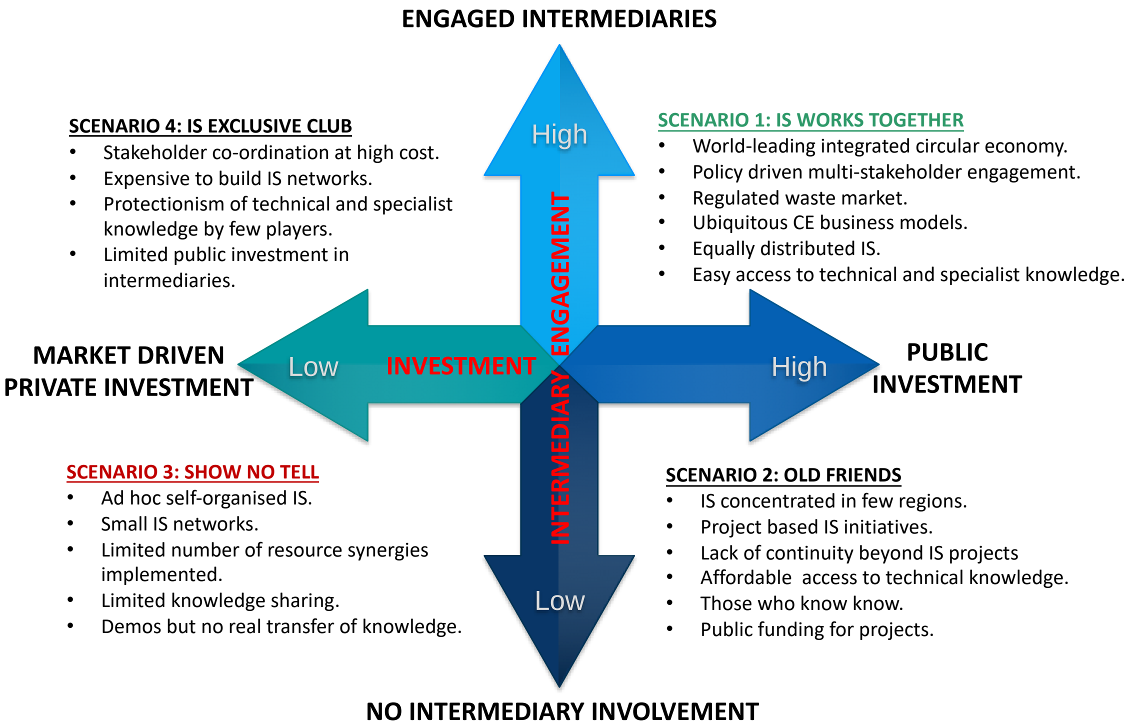

Figure 4 - Investment & Intermediaries Scenario Planning Matrix

3.1.1 Scenario 1: IS WORKS TOGETHER

Industrial Symbiosis is a complex multi-stakeholder endeavour, which would work best through a multi-lateral co-ordination and governance mechanism, i.e. Industrial Symbiosis Works Together. If we aim for a world-leading integrated circular economy in Europe, we would need policy driven multi-stakeholder engagement. This would require bold interventions and mechanisms to create and manage a regulated waste market (similar to the financial markets). Ubiquitous Circular Economy business models can enable the equal distribution of industrial symbiosis. However, this would require easy and affordable access to technical and specialist knowledge through databases that are actively managed and supported, and considerable public investment in intermediaries. IS Works Together emerges as a possible best case scenario in the matrix.

3.1.2 Scenario 2: OLD FRIENDS

In this scenario, industrial symbiosis is concentrated in few regions across Europe. It is mostly comprised of publicly-funded project-based industrial symbiosis initiatives. This scenario runs the risk of creating a lack of continuity beyond the ongoing IS projects. While access to technical knowledge may be affordable, those who know, know. This means that knowledge is constrained to the IS project participants who keep repeating the cycle of securing new IS projects over time and becoming the main holders of critical knowledge (hence Old Friends). This limits access to industrial symbiosis for new actors and prevents scale-up of IS beyond a few regions of IS excellence. This scenario emerges as the closest in direction to the current state of practice in industrial symbiosis.

3.1.3 Scenario 3: SHOW NO TELL

In this scenario, industrial symbiosis in Europe is largely self-organised and ad hoc. It is driven by opportunity rather than a deliberate strategy. We would observe small industrial symbiosis networks that manage to implement a limited number of resource synergies. This is due to limited knowledge sharing, no considerable effort from intermediaries and market driven financing. The environment is highly competitive and intermediary actors would offer demos but no real transfer of knowledge in order to retain their competitive advantage. This scenario is the least desirable from the possible futures, as it would lead to shrinking of industrial symbiosis rather than expanding it.

3.1.4 Scenario 4: IS EXCLUSIVE CLUB

The fourth scenario, entitled IS Exclusive Club, suggests that stakeholder co-ordination comes at very high cost. In this scenario, it would be expensive to build IS networks. We could observe protectionism of technical and specialist knowledge by a few players. While in Scenario 2 "Old Friends" public funding is invested in IS projects, in Scenario 4 "IS Exclusive Club", public investment is limited and primarily invested in intermediaries. This would turn intermediaries into competent powerful players but at the expense of the participation in industrial symbiosis networks by SMEs and other smaller actors.

In summary, the worst case scenario appears to be Scenario 3, entitled "Show No Tell." It is a scenario, which IS stakeholders should actively work to prevent. The best case scenario emerging from this process is Scenario 1, entitled "Industrial Symbiosis (IS) Works Together." This scenario will form part of the SCALER vision in this report.

3.2 Synergy validation

The next set of critical uncertainties that we identified from our prior research in deliverable D3.1 - namely, antecedents and technical complexity - relate to synergy validation. These critical uncertainties help to understand if a synergy is possible and if its feasibility can be validated.

Critical uncertainty 1: ANTECEDENTS

- Low = NO REFERENCE
- High = ALREADY IMPLEMENTED

Critical uncertainty 2: TECHNICAL COMPLEXITY

- Low = SINGLE PROCESS (e.g. transport)
- High = MULTIPLE PROCESSES

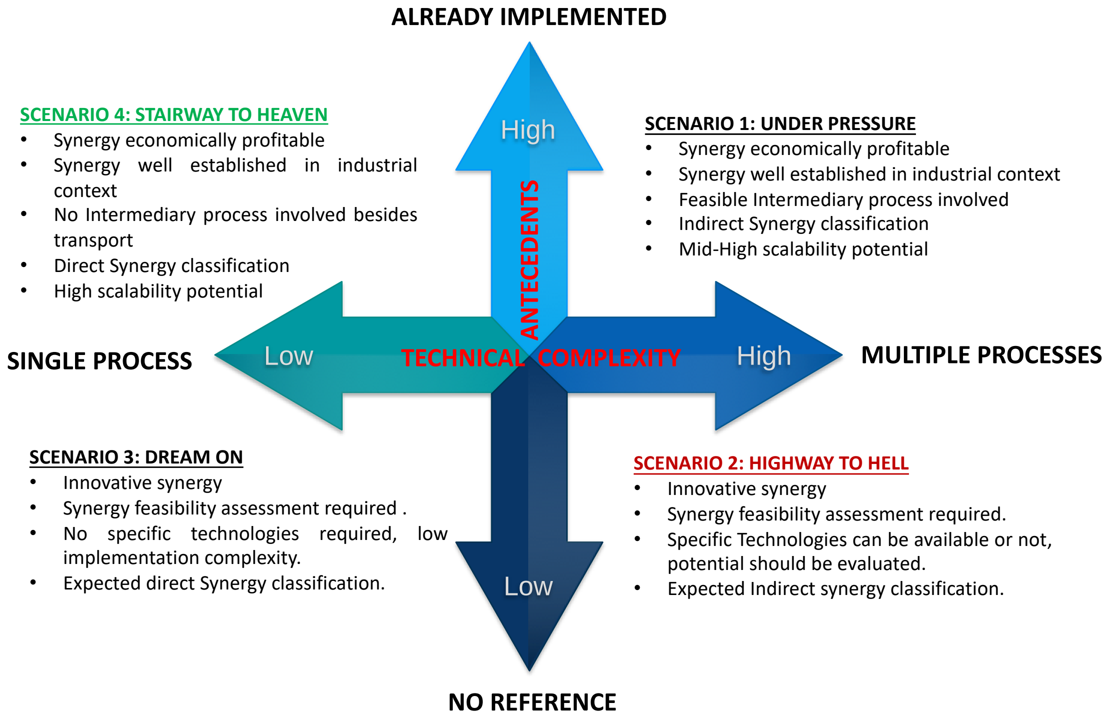

Figure 5 - Scenario Planning Matrix for Synergy Validation

3.2.1 Scenario 1: UNDER PRESSURE

This scenario can be representative of implemented and technically cost effective synergies, but dependent on multistage processes besides transportation. The need for intermediary steps before its final valorisation reduce synergies resilience level and changes on specific process variables like by-product quality can significantly affect the overall process viability. The wider implementation at European level is highly dependent on the technology availability and its industrial access at national level.

3.2.2 Scenario 2: HIGHWAY TO HELL

This is the worst case scenario regarding the technical viability of a synergy. No references to previous synergy implementation within IS processes are available, but specific technical analysis refers the need to apply numerous and complex intermediary processes for element recovery or by-product valorisation. There is a lot of uncertainty associated with the synergy viability and high risk of economic unfeasibility. Financed research projects are the most reliable way to evaluate future technical and economical synergy viability.

3.2.3 Scenario 3: DREAM ON

No references to previous synergy implementation within IS processes are available, but specific technical analysis refers to no other needs, besides transportation for element recovery or by-product valorisation. The technical complexity associated with this synergy implementation is theoretically low, thereby increasing its viability potential for future implementation. Dedicated viability analysis is required to support this optimistic scenario.

3.2.4 Scenario 4: STAIRWAY TO HEAVEN

This is the dream scenario regarding the technical viability of a synergy within the European industrial context. By-products have antecedents of valorisation within IS processes and depending only on transportation to technically implement the synergy. Logistics chains and means of transportation are highly optimized and marketplace prioritises its utilization/exchange instead of raw materials.

In summary, the worst case scenario appears to be Scenario 2, entitled “Highway to Hell.” It is a scenario, which IS stakeholders should avoid. The best case scenario emerging from this process is Scenario 4, entitled “Stairway to Heaven.” This scenario will form part of the SCALER vision in this report.

3.3 Technology selection

The next set of critical uncertainties that we identified from our prior research in D3.1 - namely, technology commercial availability and maturity - relate to technology selection. These critical uncertainties help to understand if a technology is available and Identify its maturity level.

Critical uncertainty 1: COMMERCIAL AVAILABILITY

- Low = COMMERCIALLY UNAVAILABLE
- High = COMMERCIALLY AVAILABLE

Critical uncertainty 2: MATURITY

- Low = EMERGING
- High = WIDELY IMPLEMENTED

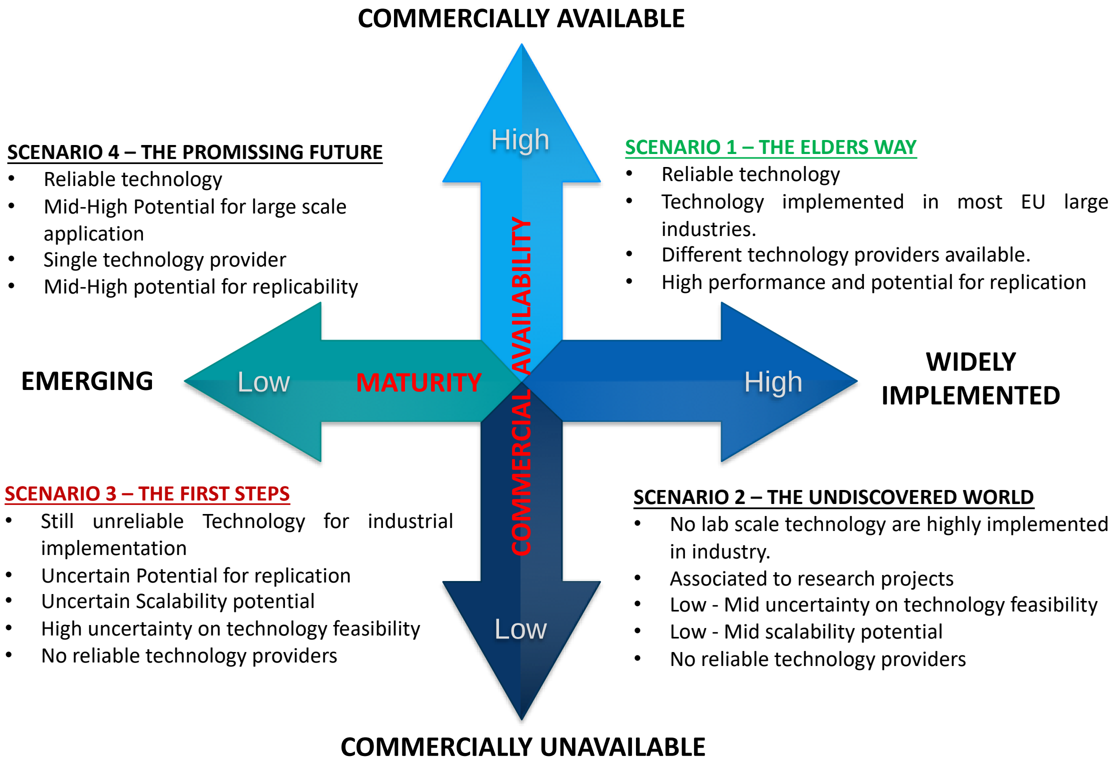

Figure 6 - Scenario Planning Matrix for Technology Selection

3.3.1 Scenario 1: THE ELDERS WAY

This is the best case scenario where maturity joins experience. The technologies required for synergies implementation have already been used for a long time and improvements on their efficiency and performance have already been undertaken. Different providers and manufacturers are available and economic competitiveness achieved, thus leading to technology popularity and high potential for replicability within other IS processes.

3.3.2 Scenario 2: THE UNDISCOVERED WORLD

This represents the most improbable but possible scenario. Normally no lab scale technology is highly implemented on industry, besides the ones associated to internal developments and to the participation on funded research projects. Internal developments can be linked to exclusivity and registration of industrial property on the developments, which is a differential factor against competitors in emerging markets. The technologies associated to funded research projects often deal with small-scale experimental tests, characterized by high levels of uncertainty in its scalability and feasibility potential.

3.3.3 Scenario 3: THE FIRST STEPS

This corresponds to the worst case scenario concerning the technology readiness for implementation. The technologies still present high uncertainty regarding their feasibility and normally they are still under development and their applicability is still under evaluation. The fact that no reliable providers are available can definitely jeopardise its replicability and scalability.

3.3.4 Scenario 4: THE PROMISSING FUTURE

This is an optimistic scenario where industries have access to reliable and commercially available technical solutions, even though they are still emerging and its utilization is scarce. This situation corresponds to those technologies that have already shown their potential, but few industries had invested on its production and utilization. The potential is high for replicability and scalability but a market driven approach and wider industrial application studies are still required.

In summary, the worst case scenario appears to be Scenario 3, entitled "The First Steps", which IS stakeholders should actively work to overcome. The best case scenario emerging from this process is Scenario 1, entitled "The Elders Way." This scenario will form part of the SCALER vision in this report.

3.4 Synergy selection

The final set of critical uncertainties relate to the selection of synergies that we identified from our prior research in D3.4 and D3.5, namely, data availability and knowledge on the end of life of resources. These critical uncertainties help to understand what synergy to select.

Critical uncertainty 1: DATA AVAILABILITY

- Low = No industrial data available (i.e. data is extracted from public bibliography)
- High = Industrial data available and shared in open access

Critical uncertainty 2: KNOWLEDGE ON RESOURCE END OF LIFE

- Low = No information on resource end of life
  (i.e. generic baseline scenarios (incineration / landfilling) not representative of the reality).
- High = Public knowledge of industrial waste fate (i.e. qualified information of the end of life allow to focus on problematic resources).

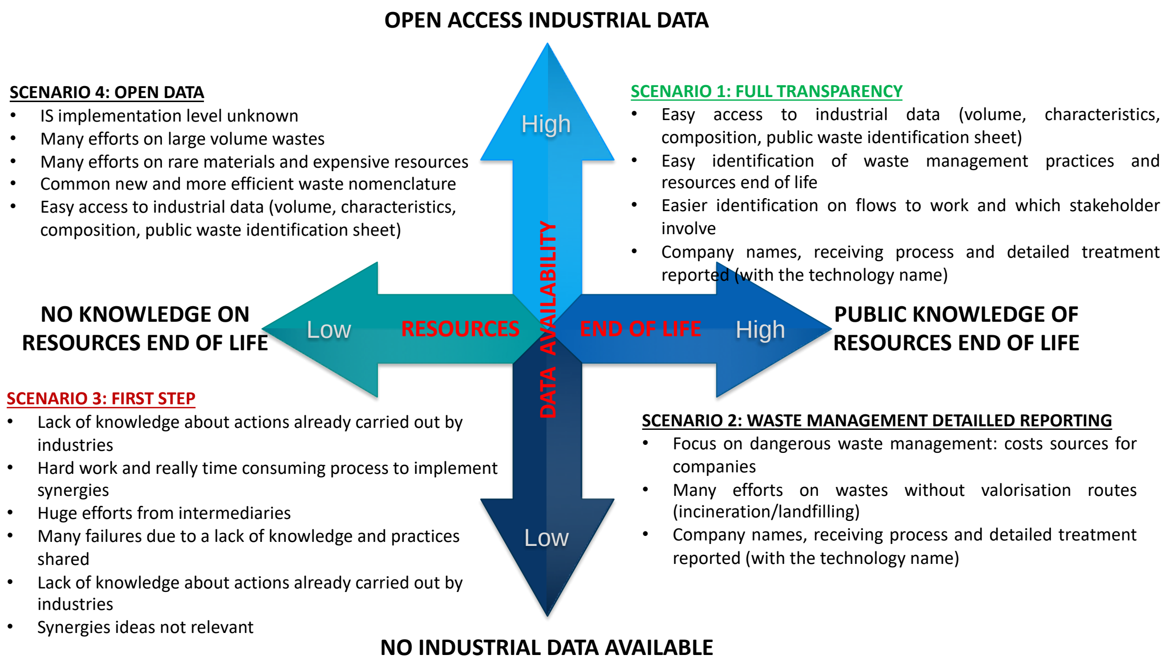

Figure 7 - Scenario Planning Matrix Synergy Selection

3.4.1 Scenario 1: FULL TRANSPARENCY

Data are collected directly from the industrial sites and the current wastes fates are publicly known. A dedicated platform well designed allow to recover and treat all data. That process involves a new European waste classification that detail al characteristics and chemical composition. That could be done by using a public and common waste identification sheet (already used between companies and waste management utilities). The scenario could be deployed with a high transparency and engagement of firms probably fostered by public investment and legal control (law) with a powerful control agency. Intermediaries have access to all data to provide solutions for IS implementation. Academics can work on new technologies to treat resources without outlet. Cities can easily coordinate the relationships between industrial actor and do not need significant support to deploy industrial symbiosis programmes. The use of artificial intelligence on the industrial network dataset allow to improve significantly the number of synergies implemented. All actors can focus on problematic resources (waste status, high impact resources, volumes) LCA and socio-economic assessment of synergies are based on relevant data with a low degree of uncertainty . Potential benefits are well quantified and help involving industrial actors.

3.4.2 Scenario 2: WASTE MANAGEMENT DETAILED REPORTING

Waste management practices and resources end of life are well known thanks to detailed, frequent and more efficient reporting (e.g. platform to enter waste management practices, survey with industrial sites and wastes managements companies, more frequent BREF update, more accurate waste treatment register). Company names, receiving process and detailed treatment are reported (with the technology name). Intermediaries and academic can focus efforts on creating new solutions for wastes without valorisation routes (incineration/landfilling). Waste valorisation practices are shared thanks to public authorities, national agencies, intermediaries and access to this detailed reporting. SMART objectives on waste landfilling and incineration reduction could by fixed more easily by cities and regional authorities for private companies. A Focus can be realized on dangerous waste management or wastes without valorisations routes: costs sources for companies. Cities and local authorities are aware about waste transferred on their geographical scope.

3.4.3 Scenario 3: OPEN DATA

The scenario requires a high transparency and engagement of firms probably fostered by public investment and legal control (law) with a powerful control agency. Industrial data could be shared through a common European well-designed platform (not private) detailing required raw materials used and generated wastes. Resources composition and characteristics need to be defined in this platform. A resource sheet model should be developed. Raw materials and wastes identification sheets models are required for these data sharing. The scenario could be deployed with a high transparency and engagement of firms probably fostered by public investment and legal control (law) with a powerful control agency. Efforts could be focused on rare earth materials, resources with extraction high environmental impact (or CO2 consuming process). Intermediaries could easily provide solution ideas but they will lack data regarding the efforts already performed and synergies already implemented by companies.

3.4.4 Scenario 4: FIRST STEP

First step is the current scenario. Only companies know resources fate and theirs IS actions. Identify synergies ideas require process industries knowledge and a huge literature review to model industrial process (raw material required and hard work to find synergies ideas and develop Hard work and really time consuming process to implement synergies because it require literature review. Intermediaries, academics and knowledge agents must deploy huge efforts to provide relevant advice and implement synergies opportunities. Cities and local authorities do not have any knowledge on industrial process and activities and cannot arbitrate. They need significant support to carry out an industrial symbiosis program including a local animation. Many failures on synergies implementation are due to a lack of knowledge and practices shared.

In summary, the worst case scenario appears to be Scenario 3, entitled "The First Steps", which represents the current state of practice and the scenario IS stakeholders should move beyond. The best case scenario emerging from this process is Scenario 1, entitled "Full Transparency." This scenario will form part of the SCALER vision in this report.

3.5 SCALER vision for Integrated European Circular Economy

The traditional scenario thinking approach is to conclude the process with the development of the future scenarios and hand the scenarios over to decision makers to determine the best way forward. However, in this report, we proactively constructed and sought the best case scenarios that could inform a desired future of widely adopted industrial symbiosis in Europe.

The SCALER vision for the wider uptake of industrial symbiosis is the summation of the best case scenarios developed in the previous chapter and the summary is presented in Table 1. It was built bottom up, synthesising critical variables from our research. The best case scenarios form an evidence-based foresight for industrial symbiosis in Europe within the constraints and limitations of the critical uncertainties that emerged from our research to date.

Table 1 - SCALER vision for Integrated European Circular Economy

INVESTMENT & INTERMEDIARIES	TECHNOLOGY SELECTION
IS WORKS TOGETHER • World-leading integrated circular economy. • Policy driven multi-stakeholder engagement. • Regulated waste market. • Ubiquitous CE business models. • Equally distributed IS. • Easy access to technical and specialist knowledge.	**THE ELDERS WAY** • Reliable technology. • Technology implemented in most EU large industries. • Different technology providers available. • High performance and potential for replication.
SYNERGY VALIDATION	**SYNERGY SELECTION**
STAIRWAY TO HEAVEN • Synergy economically profitable. • Synergy well established in industrial context. • No Intermediary process involved besides transport. • Direct Synergy classification. • High scalability potential.	**FULL TRANSPARENCY** • Easy access to industrial data (volume, characteristics, composition, public waste identification sheet). • Easy identification of waste management practices and resources end of life. • Easier identification on flows to work and which stakeholder involve. • Company names, receiving process and detailed treatment reported (with the technology name).

The following eight critical uncertainties, however, must be managed strategically so that they act as critical success factors rather than blockers for the scale-up of industrial symbiosis:

- Investment.
- Intermediary engagement.

- Synergy antecedents.
- Synergy technical complexity.
- Technology availability.
- Technology maturity.
- Data availability.
- Knowledge on resources end of life.

To conclude, the SCALER vision sets the ambition for what could be achieved in this field through co-ordinated multi-stakeholder partnerships, appropriate investment, adequate knowledge sharing and robust technology.

4. Strategy and recommendations for fostering wider application of industrial symbiosis at local, regional and European level

In the previous chapters 2 and 3, we developed the SCALER vision for an aspired future of an Integrated European Circular Economy. We took a bottom up approach to building the vision, which was grounded in the evidence and results from our research to date. This section goes a step further and presents a strategy and a set of recommendations for fostering wider application of industrial symbiosis at local, regional and European level.

4.1 SCALER strategy for industrial symbiosis

From the current futurist field, we adopt Webb's (2019) approach for strategy development (Figure 9), which provides a practical framework for constructing and visualising a roadmap for the next 10 years. According to Webb (2019), the shorter term planning offers more certainty and the longer term planning comes with less certainty, which should be taken into consideration when decision is made regarding the implementation of the strategy.

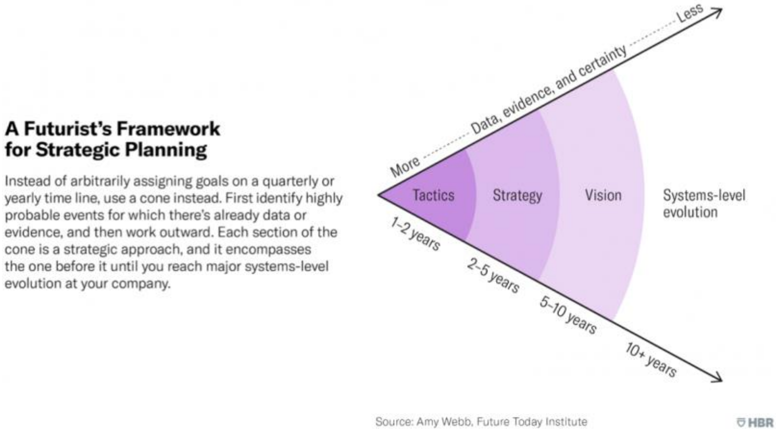

Figure 8 - Framework for strategy development (Source: Webb, 2019)

In the SCALER strategy, industrial symbiosis is seen as an opportunity that lies at the heart of an Integrated European Circular Economy. Having built the SCALER vision bottom up based on prior research, we can map the vision as the long term aspired goal. The strategy proposed below is how the vision could be accomplished. We summarise the SCALER strategy in Figure 9.

In the short term (1-3 years), efforts can be placed in tactical and operational activities by local actors. These efforts can include proactively seeking to understand the best practices in industrial symbiosis, learn about flagship case studies and experiment with tools and methods that are readily available for realising resource synergies. As a starting point, a comprehensive study of IS best practices and select case studies can be found in Scaler D2.1; and a library of tools and methods can be found in Scaler D2.4. Once such a basic knowledge foundation has been established, local actors can engage with existing networks and clusters or look for and engage with partners that can help to realise selected high-potential resource synergies. At this stage of the strategy, more experimentation is required in order to identify the most promising synergies and select the right technologies that realise these synergies. Scaler D3.1 and D3.2 offer specific reference points in support of this stage of the strategy.

In the medium term (3-5 years), efforts can be placed in more strategic activities by regional and national and actors. At this stage, the role of well-placed and well-funded intermediaries becomes critical to the long-term success of the strategy. Networks and clusters are organised and co-ordinated. Member firms/industries participate in the joint design and implementation of circular economy business models. New governance mechanisms emerge. Key reference points in support of the implementation of this stage of the strategy are Scaler D2.2, D2.3, D3.4 and D3.5.

In the long term (5-10 years), efforts can be placed by national and EU actors. These efforts should be geared directly towards the creation of an Integrated European Circular Economy, at the heart of which is industrial symbiosis. Building upon the short- and medium-term activities, the long term strategy can be achieved through consistent investment and governance. Policy-driven multi-stakeholder participation supported by local and regional technical capabilities will be key to achieving the Scaler vision. The full suite of Scaler deliverables offer various parts of the puzzle of building this future.

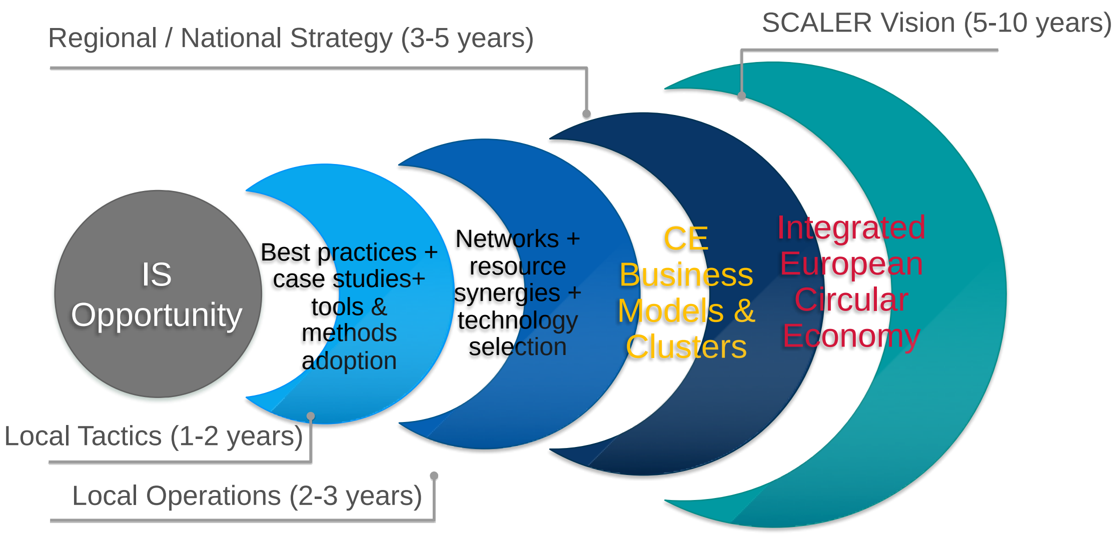

Figure 9 - SCALER Strategy for Industrial Symbiosis

4.2 Recommendations for fostering wider application of industrial symbiosis at local, regional and European level

In this final section, we propose specific recommendations aimed at industrial symbiosis actors at local, regional/national and European level. These recommendations have been derived in support of and should be understood in the context of the Scaler vision and strategy developed by the project partners in this report. It is important to note that industrial symbiosis can only be fostered through joint endeavours by actors across levels, and all have a critical role to play.

4.4.1 Recommendations for local level actors / firms

In the Scaler deliverable D2.4 “Pathways to increase industrial symbiosis including tools & methods for stakeholders”, we mapped the journey to an IS future at a local/firm level (Figure 11). The starting point of this journey is typically the discovery of value uncaptured (e.g. waste), which can unlock new opportunities through building a co-ordinated network that collectively designs and implements the right business model. The new business model can help to realise the value uncaptured and turn it into new value captured for the partners in the network. This pathway is enabled by synergy and technology selection applying available tools/methods and environmental and socio-economic assessment. This pathway is also reflected in the Scaler strategy presented in the previous section.

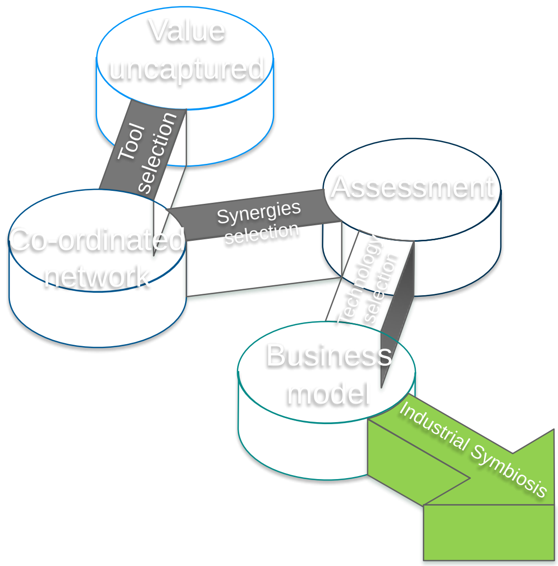

Figure 10 - Pathways for self-organised IS (Source: Vladimirova, et al., 2019 in D2.4)

In support of the strategy and this pathway, we bring the following recommendations to the fore:

- Foster strong leadership and commitment from top management to shift organisational/ corporate mindsets away from the current unsustainable paradigm and business as usual.

- Foster strong private sector leadership and build links between industry and research institutes/knowledge intermediaries that are essential for effective IS.
- Require long-term view for even modest economic, social and environmental benefits to be realised.
- Start with small initiatives and experiments that are of small scale to gradually build capability, capacity and most importantly confidence.
- Take a leading role in coordinating and developing industrial symbiosis platforms.
- Raise awareness of the potential benefits from involvement in IS initiatives.
- Firms to create dedicated organisational function to explore and drive synergistic opportunities; this delivers more rapid progress than project-based assignments that are typically given to individuals, in addition to running business as usual.
- Local authorities to create conditions for industrial symbiosis in urban areas/cities.
- Local authorities to facilitate public and private sector capabilities to form industrial symbiosis networks in an increasingly urban environment.

4.4.2 Recommendations for regional/national level actors

- IS is a complex endeavour that requires a coordinated effort among multiple public and private stakeholders that policy makers must take the lead.
- Map regional material flows.
- For IS to accelerate rapidly national governments need not only a clear, comprehensive and on-going engagement policy but a Minister and proper department/body that is accountable for delivering to specific and stretching targets.
- Within this is need for comprehensive structures (at multiple levels that are synchronised) to be established in each country; these should be fully funded by national governments. These will allow for the dynamic development of IS networks driven by on-going support and interventions that flow in succession.
- Publicise IS best practices to promote learning and knowledge sharing among regional/national actors.
- Increase efforts to include IS and circular economy activities in regional/national strategies.
- Invest in accessible high-quality specialist knowledge databases that are continuously updated and supported.

- Invest in actors with deep knowledge and expertise who understand the sectors in depth as sector-specific knowledge is critical.
- National and regional/ local government and city authorities in some places can exert powerful leverage by mandating and actively managing IS activities to ensure compliance with the national laws, in addition to supporting agencies operating at the level of EIPs and individual firms; this top-down/ bottom-up approach advances IS at greater speed than fragmented approaches elsewhere.
- Organise IS discovery and business model design workshops with world leading experts for local clusters.
- Enable and create private-public Circular Economy partnerships.
- Create conditions and build trust among industries, research institutes/knowledge intermediaries and public authorities.

4.4.3 Recommendations for European level actors

- There is an acute need for standardisation across Europe, similar to the approach taken for foods. This will allow stakeholders at all levels to develop a shared understanding.
- Need for enduring effort to support IS through direct EU and national and regional government investment; this is a pivotal enabler in starting networks and supporting the expansion of existing networks.
- Need for competitive and accessible private investment specifically designed for industrial symbiosis. Banks and finance institutions should develop the expertise for such financing and incorporate IS and circular economy initiatives in their portfolios.
- Requirement for metrics be devised and targets be set to allow direct and measurable links to be made between IS and higher productivity, while simultaneously reducing environmental impacts.
- Provide financial incentives for industry (e.g. tax exemptions) and research institutes/knowledge intermediaries (public investment) to engage with IS initiatives.
- Create a regulated waste market (similar to financial markets).

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