D3.1. Guideline Societal Embeddedness Assessment

DigiMon

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TNO Deliverable D.3.1

July 2020

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The Digimon, project no 299622 is supported by the ACT international initiative http://www.act-ccs.eu/about-us and funded by GASSNOVA (NO), RCN (NO), BEIS (UK), Forschungszentrum Jülich (DE), GSRT (GR), RVO (NL), UEFISCDI (RO), DoE (US), Repsol Norge (NO) and Equinor (NO)

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Summary

The Societal Embeddedness Level (SEL) is a novel methodology which provides insight in the societal requirements for a technological innovation to be deployed. It contributes to the realization of technological innovations in society: a societal embedded technological innovation accelerates and improves the chance of success for deployment. This methodology is developed for technological innovations that impact the environment.

Although several other readiness tools exist, they merely focus on technological aspects; the SEL methodology focuses on the societal aspects that are crucial for the further development of a technological innovation. Societal obstacles could delay or hamper its deployment. Both technical and societal factors thus influence the readiness of a technological innovation for further deployment.

The SEL is a methodology which can be used by researchers and technology developers for:

1. Assessment of the current Societal Embeddedness Level to provide insight in societal factors that are crucial for development of the technological innovation from exploration to a proven technology;
2. Providing insight into current societal challenges still to overcome towards deployment;
3. Monitoring and evaluating the societal embeddedness during technology development.

The SEL methodology builds upon the Technology Readiness Level (TRL), which assesses the maturity of technologies. The SEL is related to the TRL: for a low TRL a low SEL is sufficient, but the closer to deployment (high TRL), the higher the SEL of a technological innovation should be, taking into account all relevant societal requirements. If there is a discrepancy between the TRL and SEL– e.g. a high TRL and a low SEL – not all societal requirements are met, and the existing societal challenges need to be dealt with to reach societal embeddedness at the corresponding TRL level. Figure 1 shows the relation between the TRL and SEL.

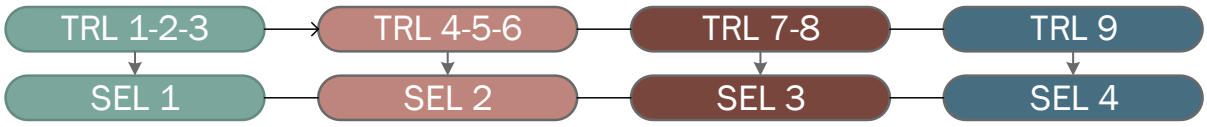

Figure 1 Correspondence between TRL and SEL

The SEL methodology distinguishes four levels of societal embeddedness and four societal dimensions, see Table *1.* The four societal embeddedness levels – which correspond to the TRL levels - are: SEL 1 Exploration, SEL 2 Development, SEL 3 Demonstration and SEL 4 Deployment. In each level four societal dimensions are taken into account: (1) Environment, (2) Stakeholder involvement, (3) Policy and Regulations and (4) Market and Financial Resources. These four dimensions influence the societal embeddedness of a technological innovation

Table 1 Visualization of the SEL Framework consisting of the four SELs and four societal dimensions

	SEL 1 Exploration	**SEL 2 Development**	**SEL 3 Demonstration**	**SEL 4 Deployment**
Dimension 1: Environment				
Dimension 2: Stakeholder involvement				
Dimension 3: Policy and Regulations				
Dimension 4: Market and Financial Resources				

The general process to assess the Societal Embeddedness Level of a technological innovation consists of the following steps:

1. Determine the reference point
2. Assess the Societal Embeddedness Level for each societal dimension
3. Identify the overall SEL and the current societal challenges

Step 1: Determine the reference point

The reference point forms the basis of the SEL assessment. The reference point of the SEL provides insight in the societal embeddedness needed for the particular technology development stage. It is determined by linking the TRL to the SEL. The reference point is the starting position to which the SEL assessment outcome is compared to.

Step 2: Assessment of SEL for each societal dimension

To provide insight in the actual SEL, an assessment for each societal dimension can be conducted. To assess the SEL of a technological innovation, an assessment framework has been developed. The SEL Framework consists of (1) milestones for each societal dimension and each level and (2) questions to be answered per milestone to evaluate if the milestone has been reached.

Step 3: Identification of current SEL and societal challenges

Based on the SEL assessment for each dimension in step 2, the overall SEL can be determined. The overall SEL is equal to the lowest level that has been reached in one of the four dimensions. Next, the overall SEL can be compared to the reference point (step 1) to identify the main societal challenges at this moment in time that need to be addressed to reach the actual reference point.

The SEL assessment outcome provides insight in the main societal challenges towards meeting the SEL reference point i.e. the point where the SEL matches the TRL. These insights can be used to determine the building blocks for a strategy to improve the societal embeddedness of the technological innovation to the most possible extent. The SEL is an interdisciplinary methodology; conducting the SEL assessment requires an interdisciplinary approach and an interdisciplinary research team.

This report presents the guideline for applying the SEL methodology and conducting a SEL assessment of a technological innovation. This guideline will be used in the ACT Digimon project for a national SEL assessment of Carbon Capture Storage (CCS) and a local SEL assessment of the Digimon monitoring system.

The structure of this Guideline is as follows. Chapter 1 presents the general introduction to the SEL methodology. Chapter 2 describes the main constructs of the SEL methodology. Chapter 3 presents the guideline for a SEL assessment. How the insight in societal challenges can be used to develop a strategy to improve the SEL is explained in Chapter 4. Chapter 5 gives insight in the application of the SEL methodology for CCS in the ACT Digimon project.

1. General introduction to SEL

1.1 Why is societal embeddedness important?

Over the years novel technologies have been developed, yet not all make it to the market. Deployment has been delayed or hampered due to technical *and* non-technical challenges. In most technology development processes, however, attention is primarily directed at technological issues, while societal aspects are often overlooked. Without proper dedication to societal requirements in the development stages of a technological innovation, the deployment can be delayed or even be obstructed. Public resistance, missing financial resources and lack of political support, are examples of societal factors that can hinder the development or deployment of novel technologies. We therefore argue that attention for the societal embeddedness of novel technologies can accelerate deployment and improve the successful realization of technologies.

The importance of addressing the societal embeddedness level of technologies is especially clear in the energy sector. Even though the R&D and innovation community is rapidly developing new energy solutions, the deployment of many of those innovations have not been achieved on a large scale. One example is CCS technology. Although a global introduction of CCS was envisioned in 2025[i], most demonstration projects that were planned have been delayed or cancelled[ii]. Many reasons for the delay or cancellation have been identified, including technological failures, rising costs[iii], lack of political support[iv], regulatory uncertainty and a lack of public acceptance[v]. These *societal* barriers need to be addressed in order to embed CCS into society.

1.2 The SEL methodology

The SEL is an interdisciplinary methodology specifically developed to assess to which extent a technological innovation meets societal requirements for deployment.[1] The methodology builds upon the Technology Readiness Level (TRL)[2] and combines elements from other readiness level tools like the Market Readiness Level[vi] and Systems Readiness Level[vii,viii] to develop a holistic methodology that combines technological with environmental, social, economic, policy and regulatory aspects. Technology and societal readiness for deployment is the scope of the SEL methodology.[3]

The SEL methodology has been developed by TNO by studying relevant existing readiness level methodologies, consulting several innovation experts with multidisciplinary expertise and performing a case study in the energy domain to further test the SEL methodology (i.e. solar parks) [ix]. The SEL methodology has been developed based on technologies in the energy sector, but is applicable in other sectors as well.

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[1] The SEL methodology is not fit for the large-scale deployment of a technology. Therefore, other methods and approaches are needed since it requires different sets of technological and societal conditions and scope.

[2] Different TRL scales are used, here we use the 9-scale based on The EU H-2020, source: cloudwatchhub. (n.d.). Readiness for Market: More than completing software development. https://www.cloudwatchhub.eu/exploitation/readiness-market-more-completing-software-development

[3] The SEL methodology is not fit for the large-scale deployment of a technology. Therefore, other methods and approaches are needed since it requires different sets of technological and societal conditions and scope.

The methodology takes into account the iterative character of the technological innovation process, wherein progress and setbacks are interchanged. The SEL methodology highlights the role of societal aspects in this iterative innovation process. The SEL methodology thus supports researchers and technology developers to develop a strategy for improving the societal embeddedness of a technological innovation[4]. Thus, the SEL methodology is:

- Linked to TRL;
- A holistic and an interdisciplinary methodology that reveals relevant societal aspects for the deployment of a technological innovation. It gives attention to setbacks through the entire development process;
- A structured methodology to analyse the societal embeddedness level of a technology and identify the societal hurdles still to overcome for deployment of a technological innovation in society;
- A methodology that is applicable to technological innovations affecting environment, independent of domain[5].

The description of the SEL methodology in this guideline reflects the current state of affairs. Nevertheless, the methodology is still in development. Via validation of the methodology in practice (i.e. case studies), we aim to further improve the SEL methodology and its applicability. In the ACT Digimon project, the SEL methodology is applied to and further developed for CCS.

1.3 Scope of this guideline

This guideline provides a step-by-step approach for (1) assessing the current SEL of a technological innovation, (2) gaining insight in the societal challenges still to overcome towards deployment of the technological innovation, and 3) developing the building blocks for a strategy to societal embedded a technological innovation based on the SEL assessment outcome. Based on this, the SEL can also be used to monitor and evaluate the societal embeddedness during technology development. The scope of this guideline is visualized in Figure 2.

4 To the most possible extent.

5 The SEL framework is implicitly modelled on a developed, liberal democracy with rather efficient organizations.

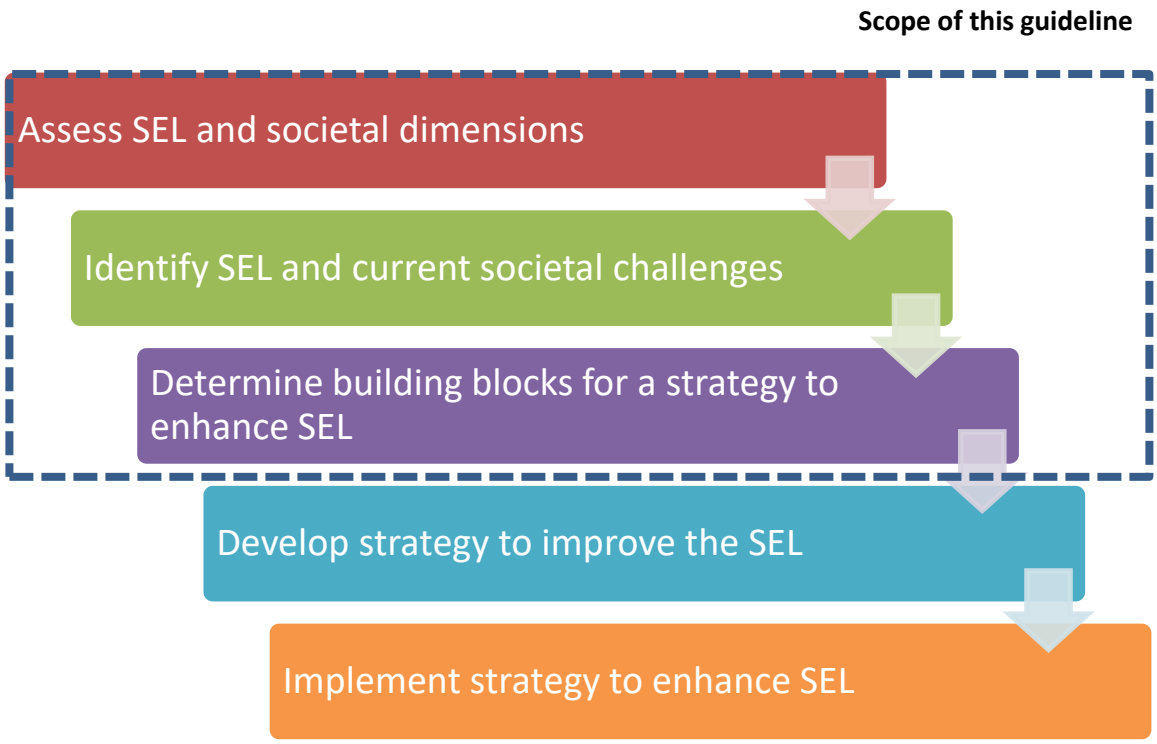

Figure 2 Overview of the scope of this guideline

Despite the benefits that the SEL methodology introduces with its focus on societal aspects, applying the methodology requires time and resources. The following is required for conducting the SEL assessment:

- Societal awareness: deployment of a technological innovation takes place in a societal context which influences the uptake of the technology (both positively and negatively);
- Time: conducting the qualitative assessment requires an investment in time at an early stage of technology development;
- Financial Resources: budget is needed to conduct the assessment;
- Human Resources: capacity is needed to conduct the assessment;
- Human Resources: an interdisciplinary research team is needed to conduct the assessment.

2. SEL methodology – main elements

The SEL methodology consists of four core elements that will be further introduced in this chapter: The TRL and the connection to SEL (section 2.1), the Societal Embeddedness Levels (section 2.2), the SEL dimensions (section 2.3) and the SEL Framework (section 2.4). Furthermore, the importance of interdisciplinarity is emphasized (section 2.5) for applying the SEL methodology as well as for optimal utilization of the SEL assessment outcomes.

2.1 SEL connection with TRL

The SEL is linked to the TRL; the 9 levels of the TRL scale[x] correspond to the 4 levels of the SEL. As such, it gives insight in what has to be done to achieve societal embeddedness of a technological innovation, from both a technological and a societal perspective. For linking the SELs to the TRLs common clusters of technology stages of the different levels are used[xi]. The relationship between the TRL and SEL is illustrated in *Figure 3*.

Figure 3 shows that a high TRL corresponds with a high SEL, while a low TRL should correspond with a low SEL, i.e. TRL 9 corresponds with SEL 4 and TRL 1-2-3 with SEL 1. We thus argue that when the technology is mature, the technological innovation should also be embedded in society in order to be deployed, i.e. TRL 9 and SEL 4.

In reality, however, we often see that technological innovations with a high TRL still face significant societal challenges, that ultimately delay and/or hamper successful deployment. Hence, a discrepancy often exists between the TRL and SEL. This discrepancy enables researchers to identify what needs to be addressed to further develop the technological innovation towards societal deployment. As a result, the parallel assessment of the TRL and the SEL provides an answer as to what should be done to embed to the most possible extent the technological innovation in society[6].

[6] A high SEL-score can increase the chances of successfully implementing new technological innovations, but it does not necessarily condition this.

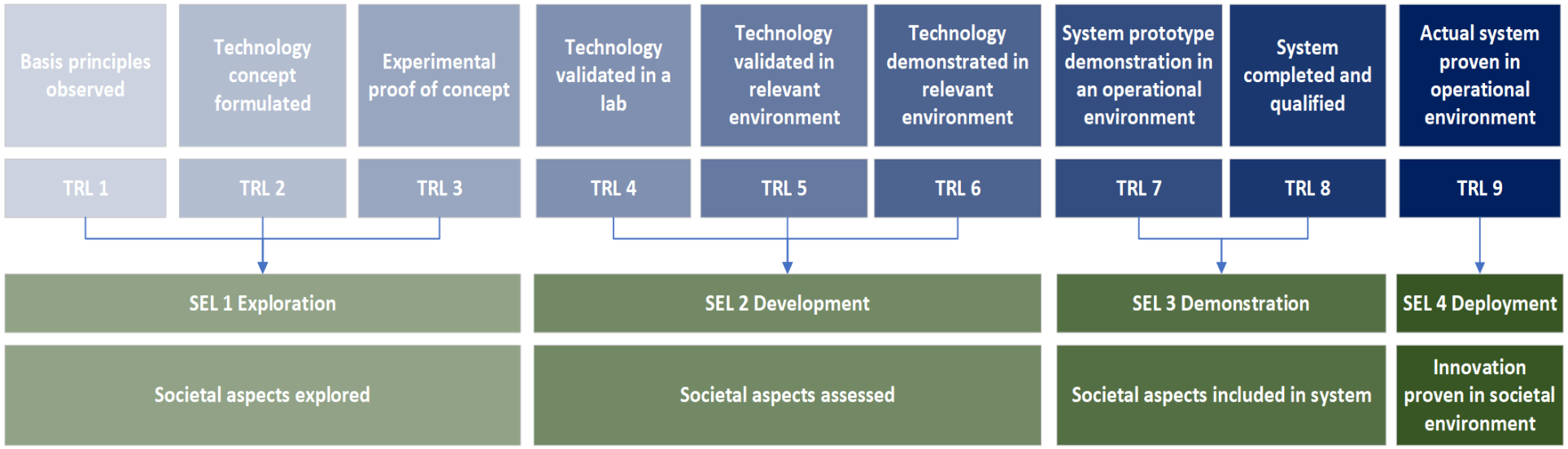

Figure 3 Connection between TRLs[xii] and SELs

2.2 Four Societal Embeddedness Levels

As indicated in section 2.1, we distinguish four Societal Embeddedness Levels (SEL) related to the development stage of the technology (and TRL), see Figure 4.

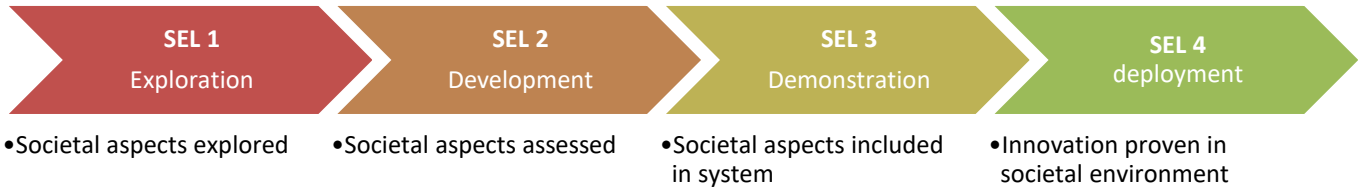

Figure 4 The labels of the four Societal Embeddedness Levels

These four SELs are characterized as follows:

1. SEL 1 Exploration: The basic principles of the technological innovation are observed, the technology concept is formulated and an experimental proof of concept has been done. In SEL 1 the possible impact of the innovation concept on the natural, built and social environment, the stakeholder interests and attitude, the existing policy and regulations and the market and financial resources are explored. SEL 1 matches TRL 1, 2 and 3.

2. SEL 2 Development: The technology is validated in a lab and is demonstrated in a relevant environment. SEL 2 elaborates on and deepens the exploration that has been done in SEL 1 by assessing, rather than exploring, the impact of the technology on the natural, built and social environment, the stakeholders' perceptions and concerns, (drivers and barriers of) the policy and regulations, the market needs and trends and development of a first business case. SEL 2 matches TRL 4, 5 and 6.

3. SEL 3 Demonstration: The technology and its system[7] are demonstrated in an operational environment and the system is complete and qualified. SEL 3 is about designing the societal factors of the whole system, based on requirements for environment, stakeholders, policy and regulations and the market. In SEL 3 there is ongoing research on implications of the technological innovation, and legal experimentation exceptions might apply, e.g. experiment laws and regulations. SEL 3 matches TRL 7 and 8.

[7] Systems necessary for the innovation to work in its operational environment, limited to technologies and artefacts, which can – at the same time – be a part of the built environment.

4. SEL 4 Deployment: The technological innovation is proven in an operational environment. The system is embedded in society by meeting the essential societal conditions: harm to the physical and social environment is as low as reasonably achievable, support by relevant stakeholders and stakeholder involvement for deployment, supporting policy and regulations, financial support and a solid business case for deployment. SEL 4 matches TRL 9.

Example technology and it's system

The SEL of the technological innovation of electric driving is assessed. The technology, the most important part of the technological innovation, is the electric car. However, to be able to use the electric car, certain systems are required, such as charging stations and batteries. The technology and its system(s) jointly form the technological innovation (electric driving).

To further deploy a fully societal embedded technological innovation after SEL 4, other methodologies focused on large scale deployment such as innovation system analysis, market analysis, etc. are available.

2.3 Four SEL dimensions

The SEL methodology distinguishes four SEL dimensions: 1) Environment, 2) Stakeholder involvement, 3) Policy and Regulations and 4) Market and Financial Resources. These four dimensions primarily determine the societal embeddedness of a technological innovation. While there are other aspects important for successful deployment of a technological innovation, like organization, capacity, expertise and skills – these are not a separate dimension or included within the dimensions, because they are internal organizational aspects which do not have direct impact on the societal embeddedness[8]. The four dimensions do not operate in a vacuum and are influencing each other. Table 2 illustrates a brief summary of the activities in the four SEL dimensions that need to be undertaken to achieve societal embeddedness for small-scale deployment.

[8]Not taken into account is: strategic behaviour of actors in the innovation system and the interaction with other innovation (e.g. path-dependency, lock-in), inter-organisation factors (e.g. organization culture, behavior employees).

Table 2 Description of the SEL dimensions

SEL dimension	Description
Environment	Keep harm to the environment as low as reasonably achievable by exploring and assessing the impact of the innovation on the environment. The technology can be adapted to make the (negative) environmental impact as low as possible. This dimension includes the natural, built and social environment of the technological innovation.
Stakeholder involvement	Support of relevant stakeholders for the technological innovation through stakeholder participation in the different stages of technology development. It includes exploring and assessing stakeholders' needs and concerns regarding the technological innovation. The insights are translated and integrated into the further development of the technological innovation.
Policy and Regulations	Establishment of supporting policies and regulations for the technological innovation. This dimension includes exploring and assessing policy and regulatory drivers and barriers for the different development stages of the innovation towards deployment.
Market and Financial Resources	Market is ready for adoption of the technological innovation and financial resources are available for technology development towards deployment. This dimension includes funding for research and development, identifying market needs, assessing market dynamics and developing a solid business case.

2.4 Framework for assessing the SEL

The SEL assessment framework is designed to determine the SEL of a technological innovation. The four societal embeddedness levels (section 2.2) and the four SEL dimensions (section 2.3) form the basis of this framework. In this framework, every societal dimension is translated into a unique set of milestones. These milestones are set per SEL. Table 3 illustrates the combination of the four SELs, the four societal dimensions and their milestones. For each SEL- Societal dimension combination, a unique set of questions has been formulated to assess whether the technological innovation meets the milestone. Table 3 displays a simple visualization of the SEL framework with milestones, the SEL framework with the set of questions can be found in Appendix 6.2.

Table 3 Visualization of the SEL Framework with the four SELs and four societal dimensions, with milestones

	SEL 1 Exploration	**SEL 2 Development**	**SEL 3 Demonstration**	**SEL 4 Deployment**
Dimension 1: Environment	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4
Dimension 2: Stakeholder involvement	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4
Dimension 3: Policy and Regulations	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4
Dimension 4: Market and Financial Resources	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4	☐ Milestone 1 ☐ Milestone 2 ☐ Milestone 3 ☐ Milestone 4

2.5 Interdisciplinarity

Use of the SEL methodology requires interdisciplinary expertise: assessing the Societal Embeddedness Level of a technological innovation requires insight in the stage of technological development and careful examination of the various dimensions of the SEL. Scientists from different backgrounds and disciplines (e.g. technicians, engineers, social scientists, legal, etc.) need to collaborate to assess the SEL and to define the strategy and actions to progress the SEL. The following is required for the interdisciplinary research team to apply the SEL methodology:

- Expertise on all four dimensions, i.e. on the natural, built and social environment, stakeholders involvement processes, market dynamics and business cases, policy and regulations and the technological innovation itself;
- Expertise on and experience with societal research;
- Capability to translate outcomes of the SEL assessment into a strategy to cope with both technical and societal challenges.

Although the SEL framework can be applied in a multidisciplinary way (i.e. approaching the problem from different disciplines), we suggest that SEL can be improved by interdisciplinary (i.e. integration of knowledge from different disciplines) and/or transdisciplinary (i.e. working from different disciplines on joint goals) collaboration (see **Error! Reference source not found.**)[9].

Table 4 Differences between multi- inter – trans – disciplinary research[xiii]

Multidisciplinary research	**Interdisciplinary research**	**Transdisciplinary research**
Researchers work parallel or sequentially. There is cooperation between disciplines, but no integration of knowledge. Each researcher works with his/her own framing or method of its own discipline.	Interaction between researchers from different disciplines lead to new understandings. There is integration of knowledge. The joint development of a conceptual framework and joint collection and analyzing of data by researchers is an advanced form of interdisciplinary research.	A wide diversity of disciplines fused together, working towards common research objectives. This also includes other forms of knowledge and experience derived from a wide range of stakeholders and practitioners, such as policy makers, involved businesses, and citizens.

[9] For a recent overview of multi-, inter-, and transdisciplinary science and its requirements see: Moiranoa,R., Sáncheza, M.A., Štěpánek, L. 2020, Creative interdisciplinary collaboration: A systematic literature review, Thinking Skills and Creativity 35 (2020) 100626, https://doi.org/10.1016/j.tsc.2019.100626

Inter- and transdisciplinary approaches to assess the SEL require a sound process of interaction between the involved scientists (and stakeholders) to integrate knowledge for the SEL assessment. A sequence of knowledge integration workshops with time in-between to research certain factors is advisable. In order to be effective and efficient, the process requires a knowledgeable facilitator. This facilitator should preferably be a person who is able to overlook the involved disciplinary knowledge and is experienced in organizing and facilitating interaction processes for problem solving.

3. SEL Assessment guideline

3.1 Stepwise process to assess the societal embeddedness

The societal embeddedness of a technological innovation can be assessed in three successive steps which are described in the following sections and presented in Figure 5.

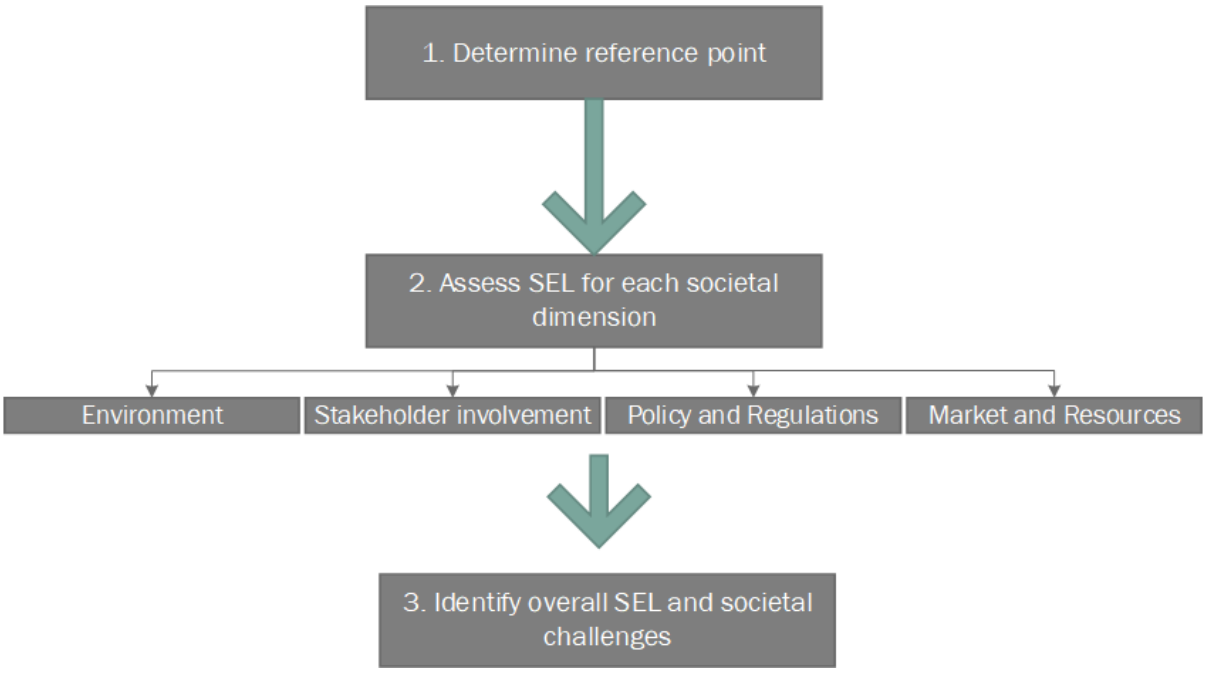

Figure 5 Stepwise process to assess the SEL of a technological innovation

3.1.1. Step 1: Determine reference point

The first step provides insight in the SEL that would be expected based on the current TRL of the technology: the reference point. As stated in chapter 2, every SEL is linked to a cluster of TRL's. The identified TRL determines at which SEL the technological innovation should be at that particular technology development stage, this is called the reference point of the SEL. Figure 6 displays how the SEL relates to the TRL.

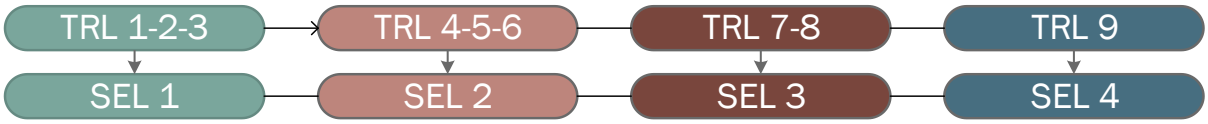

Figure 6 Corresponding TRLs and SELs

To promote successful deployment of a technological innovation, the societal embeddedness level should increase parallel with the advancing of the maturity of the technology, which is indicated by the TRL. Related to the TRL, the required SEL can be characterized as follows[10]:

SEL 1: exploration	Societal embeddedness that is required for a technological innovation at the early stage of concept development, i.e. basic principles observed, technology concept formulated and experimental proof of concept.
SEL 2: development	Societal embeddedness that is required during technology validation in controlled environment, i.e. technology validated in lab, technology validated in relevant environment and technology demonstrated in relevant environment.
SEL 3: demonstration	Societal embeddedness that is required during technology pilot demonstration in practice (technology and its system), i.e. system prototype demonstration in an operational environment and system completed and qualified.
SEL 4: Deployment	Societal embeddedness that is required for the market introduction of the new technology, i.e. technological innovation (technology and its system) that has proven to work and is ready for deployment.

The next step is to assess the SEL for each dimension. The reference point is the starting position to track the motion of the SEL: the outcome of the SEL assessment is compared to the reference point. The gap between the reference point and the actual SEL per dimension indicates the societal challenges.

3.1.2. Step 2: Assess SEL for each dimension

The SEL assessment for each dimension indicates whether the reference point determined in step 1 is the actual SEL of the technological innovation at this particular moment in time. The SEL framework supports the assessment with milestones that need to be reached and questions per milestone to be answered for each SEL dimension. Appendix 6.2 presents the complete SEL framework with the milestones and questions. The dimensions can be assessed parallel or independent. The order of conducting the assessment for the dimensions does not matter as long as all dimensions are assessed.

[10] TRLs are clustered according to European standards

The assessment of the SEL of each societal dimension consists of four sub steps:

1. The reference point determined in step 1 is the starting position of the SEL assessment, i.e. SEL 1, SEL 2, SEL 3 or SEL 4.

2. What is already known on the SEL dimensions? Gather and assess relevant information on any of the SEL dimensions and use it for the SEL assessment.

3. Answer the questions per milestone in the SEL framework. Use the information that is already gathered and assessed. Explain why a milestone has or has not been reached. Examples of supporting methods and tools to these answer research questions are summarized in Appendix 6.3.

4. Identify SEL for each dimension and explain why.

The outcome of step 2 – assessing the SEL level per societal dimension – gives an overview of the actual SELs of the technological innovation per dimension. Not every dimension has to be at the same level. *Figure 7* therefore presents how the answers can determine the SEL for each dimension. Ideally, all dimensions are at the same level (vertical). However, it is possible that one dimension is at a higher level than the other. Moving one level higher or one level lower can only occur within one dimension; horizontal.

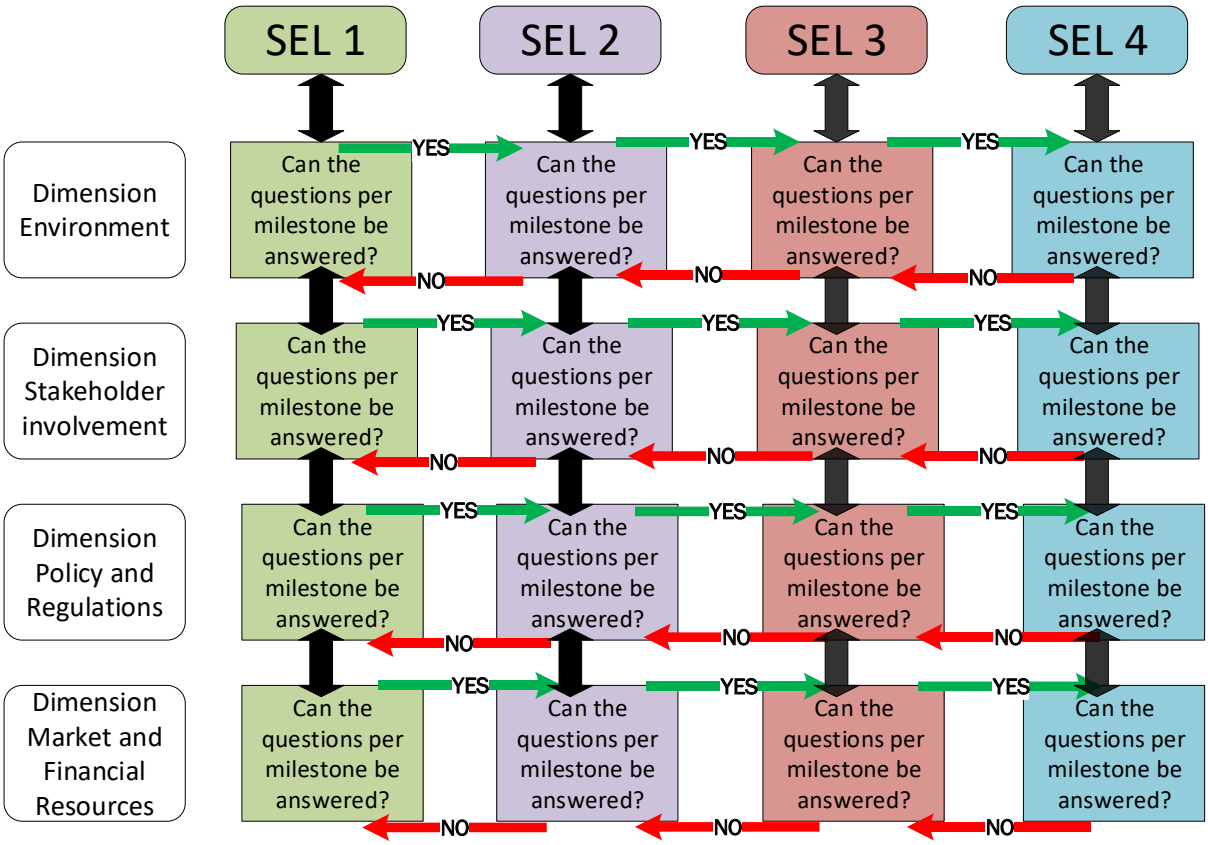

Figure 7 Flowchart moving within a dimension between levels by answering questions per milestone.

Per dimension and level, the question is asked whether the milestones have been achieved. Every milestone has a unique set of research questions that need to be answered to reach the milestone. See Appendix 6.2 for the SEL Framework assessment tables. Additional information on levels, dimensions, and key concepts – like environment or system – can be found in the glossary (Appendix 6.1).

During the technology development process the SEL should be monitored to detect progress or setbacks. Setbacks can occur during the process of advancing through the SEL levels. If a setback occurs, one or more dimensions relapse to a lower level.

Example setbacks:

Municipalities can stop providing permits for solar parks as a result of negative media attention and resistance of the public stakeholders. In this case an event in dimension 2 causes an event in dimension 3 (refined rules for obtaining permits), which can lead to a setback to a lower SEL value in dimension 3.

3.1.3. Step 3: Identify overall SEL and related societal challenges

The overall SEL and related societal challenges can be identified in the following three sub steps:

1. Identify overall SEL based on SEL assessment outcome
2. Compare reference point with the SEL assessment outcome
3. Identify societal challenges if there is a gap between the reference point and the SEL assessment outcome

Sub step 1: Identify overall SEL

The overall SEL of a technological innovation is equal to the lowest reached SEL in one of the four dimensions. An example result of the SEL assessment outcome for each dimension is displayed in *Table* 5. The example shows that the lowest SEL reached is level 2, and therefore the overall SEL is set at 2.

Table 5 Example result of SEL outcome for each dimension, with reference point SEL 4

	SEL 1 Exploration	**SEL 2 Development**	**SEL 3 Demonstration**	**SEL 4 Ready for deployment**
Dimension 1: Environment	All milestones reached	All milestones reached	Not all milestones reached	Not all milestones reached
Dimension 2: Stakeholder involvement	All milestones reached	All milestones reached	Not all milestones reached	Not all milestones reached
Dimension 3: Policy and Regulations	All milestones reached	All milestones reached	All milestones reached	Not all milestones reached
Dimension 4: Market and Financial Resources	All milestones reached	All milestones reached	All milestones reached	All milestones reached

Sub step 2: Comparison reference point with the SEL assessment outcome

The discrepancy between the SEL reference point (step 1) and the SEL assessment outcome (step 2 and 3) determines the extent of the societal challenges. When there is a discrepancy, there are still societal challenges to be addressed to achieve coherence between the reference point and the SEL assessment outcome.

Sub step 3: Identify societal challenges

The value of the outcome of the SEL assessment lies in the understanding of which societal challenges need to be addressed to improve the SEL towards coherence between the SEL reference point and the SEL assessment outcome: the SEL milestones that have not yet been reached indicate the societal challenges that need to be addressed..

The societal challenges should be identified based on the assessed SEL dimensions. For the example in Table 5, the societal challenges towards the reference point (in this case deployment) lie primarily with the SEL dimension 'environment', and the SEL dimension 'stakeholder involvement' and secondarily with the SEL dimension 'policy and regulations'. In this example the SEL dimension of market and financial resources, doesn't pose any challenges based on SEL outcome. The particular milestones that have not been reached within the SEL dimensions indicate the specific societal challenges that need to be addressed to achieve a higher SEL. Figure 8 illustrates an example

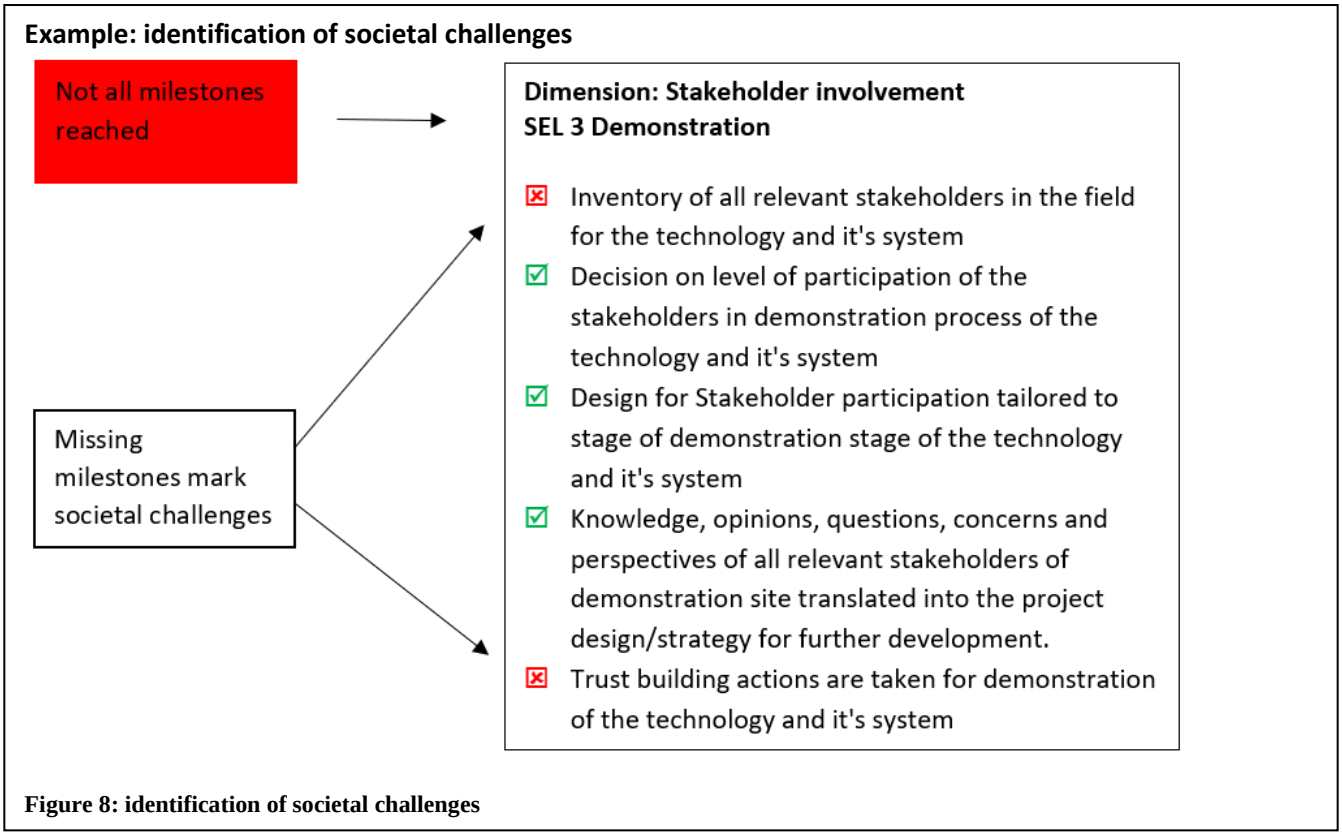

Figure 8: identification of societal challenges

4. From SEL assessment to strategy formation to enhance SEL

The SEL assessment outcome provides information on the remaining societal challenges which need to be addressed. This chapter elaborates how these insights can be used as building blocks for the development of a strategy to enhance the SEL.[11]

To identify the building blocks for the strategy to enhance the SEL, the following questions can be asked:

- Which societal dimensions need attention?
- Which milestones still need to be achieved within the societal dimensions?

The answers to the questions above can be derived from the SEL assessment outcome (chapter 3).

The starting point for the strategy is the discrepancy between the reference point and the outcome of the SEL assessment. This discrepancy indicates what is needed to improve the SEL until it is equal to the SEL reference point. For this catching-up effort, the identified societal challenges have to be addressed. If the reference point corresponds with the assessed SEL, the strategy objective is to improve the SEL towards SEL 4: (readiness for) deployment. This should be done parallel to the technology development, so the SEL and TRL improve parallel. The monitoring and evaluation of the SEL to detect and act on setbacks during the technology development can also be part of the strategy.

A variety of methodologies and tools can support the answering of the questions and reaching the milestones to enhance the SEL, for example:

- Desk study
- Interviews with stakeholders
- Surveys
- Stakeholder analysis tools and methods
- Stakeholder involvement and engament approaches
- Environmental impact assessments
- Institutional analysis
- External strategic analysis

An overview of supporting methods and tools to answer the questions per milestone is presented in Appendix 6.3.

[11] Not every result from the SEL assessment may present a challenge to overcome; some technologies may have such negative impacts on the natural/social/built environment that further development is not warranted. This is something that needs to be taken into account before proceeding to develop a strategy for enhancing the SEL.

Methodologies and tools that can be used to reach the SEL for each level are:

SEL 1 exploration: First study on the societal dimensions. In-depth literature analyses of policy documents, scientific literature, online/social media sources and research projects can be used to collect the required information to answer the research questions in level 1.

SEL 2 development: Fundamental research on the societal dimensions. Methods and tools to collect profound information. Parallel to continuing desk research, methods like surveys, interviews with stakeholders, other stakeholder analysis methods and tools and participation methods can be used at this level.

SEL 3 demonstration: Research activities are continued by monitoring the societal dimensions, dynamics, possible setbacks during the demonstration phase –and if required adjustments and improvements are made for societal embeddedness of the technological innovation at this level. Specific at this stage are participation methods which should be used for active involvement of stakeholders during demonstration of the technological innovation, for instance with interviews, evaluation questionnaires, workshops and focus groups.

SEL 4 deployment: Adjustments are made to integrate the societal aspects into the system to embed it fully in society for deployment. Societal hurdles have been tackled or mitigated.

The use of methods and tools to answer the research questions is context specific, there is no one-size fits all solution, and the methodology choice depends, for instance, on data availability, available capacity, data sources, available expertise, skills and experience. Appendix 6.3 displays examples of methods and tools that support the activities which form the strategy to enhance the SEL.

5. Further development of the SEL: Applying the SEL methodology to CCS in ACT Digimon

One of the objectives of the Digimon project is to develop a human-centred monitoring system for CO2 storage projects. Our next step is therefore to apply the SEL framework to CCS in the Digimon project. After all, the SEL methodology is not only meant to identify the current SEL and the societal challenges to be addressed to increase the SEL of a technological innovation. The SEL methodology is also meant as a monitoring tool, that enables innovators and companies to track the SEL level during the development of the technological innovation. This is what we aim to explore further in the Digimon project.

The aim of the application in practice is threefold. First, we aim to gain insights into the main societal challenges for deployment of CCS. Second, we aim to further develop the SEL framework by applying it in practice. Third, we aim to tailor the SEL framework towards a human-centred monitoring system. The following next steps have therefore been identified.

First, we will apply the SEL methodology to CCS in four cases at national level: Norway, Germany, Greece and the Netherlands. This means that we will start with an assessment of the societal embeddedness level of CCS in four countries. This assessment will give insight into the societal challenges that need to be addressed during further development of CCS projects in these countries.

Second, the national assessment will give us feedback on how the SEL methodology works, how it could be further improved, and how sensitive it is to country differences.

Third, based on the outcomes of the national assessments, we aim to identify those societal challenges that are related to monitoring and/or could be tackled by designing a human-centred monitoring system. Based on this analysis, we want to be able to tailor the SEL assessment to the Digimon system and its application at local level. Therefore, we will select three local case studies in three different countries, in which the Digimon system will or could be implemented. For these local case studies we will analyse how the Digimon system contributes to meeting the identified societal requirements at stake. With the outcomes of the local assessments we aim to identify 1) generic monitoring requirements which contribute to improving the societal embeddedness of a CCS project as well as to 2) develop a storyline on the value of the Digimon system and how it contributes to developing societally embedded CO2 storage projects.

Both the national and the local assessments will be executed by an interdisciplinary research team, in which many Digimon researchers will be involved.

6. Appendix

6.1 Glossary

6.2 SEL Framework assessment tables

6.3 Examples supporting methods and tools to answer questions

6.4 References

6.1 Glossary

Societal embeddedness	The extent to which the technological innovation meets societal requirements.
SEL	Societal Embeddedness Level (SEL): the extent to which a technological innovation is embedded in society, expressed in four levels on 4 societal dimensions.
SEL methodology	The Societal Embeddedness Level (SEL) is a novel methodology to assess the extent to which the technological innovation meets societal requirements towards deployment.
SEL assessment	An approach to measure the specific SEL of a technological innovation.
SEL framework	An instrument to assess the SEL of a technological innovation. The SEL framework consists of milestones to be reached and questions to be answered per dimension and per level towards deployment. It can be used to conduct the SEL assessment.
Exploration (SEL 1)	Exploring the possible impact of the innovation concept on the physical and social environment, the stakeholder field and attitude, the existing policy and regulations, as well as the market and financial resources.
Development (SEL 2)	Assessing the impact of the technology on the natural, built and social environment, the stakeholders' perceptions and concerns, (drivers and barriers of) the policy and regulations, the market needs and trends and development of a first business case.
Demonstration (SEL 3)	Designing the technology and its system, based on requirements for environment, stakeholders, policy and regulations and the market. There is ongoing research on implications, and experimentation exceptions might apply, e.g. experiment laws and regulations.
Deployment (SEL 4)	Technological innovation (technology and its system) is embedded in society by meeting the essential societal conditions: harm to the natural, built and social environment is as low as reasonable practicable, support by relevant stakeholders and stakeholder involvement in implementation, supporting policy and regulations, financial support and a solid business case for implementation. At this point, the technological innovation is ready to be deployed.

Environment	The first societal dimension - The natural, built and social environment of the technological innovation in the stages of exploration, development, demonstration and deployment.
Natural environment	Naturally occurring living and non-living things, like water, air, land and living species[xiv].
Built environment	The human-made environment that provides the setting for human activity (buildings, cities and beyond), for example buildings and spaces that are created or modified by human. Electric transmission lines and landfills (underground) are part of the built environment as well[xv].
Social environment	The actual physical and social context in which people live and things happen and develop. It includes the culture that people are educated or live in as well as institutions with whom they interact[xvi].
Stakeholder involvement	The second societal dimension - The involvement of organizations and/or individuals who may be affected by the innovation or who can influence the exploration, development, demonstration and deployment of the technological innovation.
Policy and regulations	The third societal dimension - Policies are rules that are made by organizations or governments to achieve their aims and goals. Regulations are rules that are made to make organizations or individuals comply and behave in a certain manner. Policies and regulations can act as drivers and barriers for the exploration, development, demonstration and deployment of the technological innovation
Market and financial resources	The fourth societal dimension - The economic and commercial environment in which the innovation operates and the financial resources that are needed for exploration, development, demonstration and deployment of the technological innovation.
SEL milestone	A SEL milestone is a significant stage in the societal embeddedness of a technological innovation for small-scale implementation.
SEL question	Dichotomous questions which indicate whether a milestone has been reached.
Technological innovation	A technological innovations is a new product or process or a significant technological change of a products or process[xvii].
Technology	Science or knowledge practically applied to solve problems or invent tools. In this report we refer to technology as the device which is needed for the innovation. The technology is the most important part of the

	technological innovation. The technology is developed alone during TRL 1 – 6 and is societally embedded during SEL 1 – 2.
System	Systems necessary for the innovation to work in its operational environment, limited to technologies and artefacts, which can – at the same time – be a part of the built environment. These systems can be existing as well as still under development. If the systems are still under development they have to undergo the first two levels of the SEL assessment as key-system as well. The system is added to the technology in TRL 7 – 9 and SEL 3 – 4.
Technology and its system	The technology and its system is equal to the technological innovation that is assessed.
Reference point	The SEL reference point is the SEL level that should be reached at a certain point in technology development and is determined by linking the TRL to the SEL.
Societal challenge	A societal problem that needs to be addressed to enhance the SEL up to the reference point.
SEL Setback	Going back from a higher to a lower level of societal embeddedness, caused by an event in one of the (other) dimensions.
Interdisciplinarity	Involving more than one different subjects of branches of knowledge in a common task.
SEL guideline	A statement by which to determine the course of action in applying the SEL methodology.

6.2 SEL Framework assessment tables

Dimension 1: Environment

	SEL 1 exploration		
Milestone 1	Identification of natural environment of the innovation concept	*Question 1*	Is the state of the art on land explored?
		Question 2	Is the state of the art on air explored?
		Question 3	Is the state of the art on water explored?
		Question 4	Is the state of the art on life explored?
Milestone 2	Identification of built environment of the innovation concept	*Question 1*	Is the state of the art on buildings explored?
		Question 2	Is the state of the art on spaces explored?
		Question 3	Is the state of the art on infrastructure explored?
Milestone 3	Identification of social environment of the innovation concept	*Question 1*	Is the state of the art on social relationships explored?
		Question 2	Is the state of the art on cultural milieus explored?
		Question 3	Is the state of the art on institutions explored?
		Question 4	Is the state of the art on immediate physical surroundings explored?
Milestone 4	Exploration of potential impact of the innovation concept on the Natural environment	*Question 1*	Are the potential impacts on land explored?
		Question 2	Are the potential impacts on air explored?
		Question 3	Are the potential impacts on water explored?
		Question 4	Are the potential impacts on life explored?
Milestone 5	Exploration of potential impact of the innovation concept on the built environment	*Question 1*	Are the potential impacts on buildings explored?
		Question 2	Are the potential impacts on spaces explored?

		Question 3	Are the potential impacts on infrastructure explored?
Milestone 6	Exploration of potential impact of the innovation concept on the social environment	*Question 1*	Are the potential impacts on social relationship explored?
		Question 2	Are the potential impacts on cultural milieus explored?
		Question 3	Are the potential impacts on institutions explored?
		Question 4	Are the potential impacts on immediate physical surroundings explored?
	SEL 2 development		
Milestone 1	Identification of natural environment of the system	*Question 1*	Is the state of the art on land explored?
		Question 2	Is the state of the art on air explored?
		Question 3	Is the state of the art on water explored?
		Question 4	Is the state of the art on life explored?
Milestone 2	Identification of built environment of the system	*Question 1*	Is the state of the art on buildings explored?
		Question 2	Is the state of the art on spaces explored?
		Question 3	Is the state of the art on infrastructure explored?
Milestone 3	Identification of social environment of the system	*Question 1*	Is the state of the art on social relationships explored?
		Question 2	Is the state of the art on cultural milieus explored?
		Question 3	Is the state of the art on institutions explored?
		Question 4	Is the state of the art on immediate physical surroundings explored?
Milestone 4	Potential impacts of the system on the natural environment are explored	*Question 1*	Are the potential impacts of the system on land explored?
		Question 2	Are the potential impacts of the system on air explored?
		Question 3	Are the potential impacts of the system on water explored?
		Question 4	Are the potential impacts of the system on life explored?

Milestone 5	Potential impacts of the system on the built environment are explored	*Question 1*	Are the potential impacts of the system on buildings explored?
		Question 2	Are the potential impacts of the system on spaces explored?
Milestone 6	Potential impacts of the system on the social environment are explored	*Question 1*	Are the potential impacts of the system on social relationships explored?
		Question 2	Are the potential impacts of the system on cultural milieus explored?
		Question 3	Are the potential impacts of the system on institutions explored?
		Question 4	Are the potential impacts of the system on immediate physical surroundings explored?
Milestone 7	The impact(s) of the technology on the natural environment are assessed	*Question 1*	Are the impacts of the technology on land assessed?
		Question 2	Are the impacts of the technology on air assessed?
		Question 3	Are the impacts of the technology on water assessed?
		Question 4	Are the impacts of the technology on life assessed?
Milestone 8	The impact(s) of the technology on the built environment are assessed	*Question 1*	Are the impacts of the technology on buildings assessed?
		Question 2	Are the impacts of the technology on spaces assessed?
		Question 3	Are the impacts of the technology on infrastructure assessed?
Milestone 9	The impact(s) of the technology on the social environment are assessed	*Question 1*	Are the impacts of the technology on social relationships assessed?
		Question 2	Are the impacts of the technology on cultural milieus assessed?
		Question 3	Are the impacts of the technology on institutions assessed?
		Question 4	Are the impacts of the technology on immediate physical surroundings assessed?
	SEL 3 demonstration		
Milestone 1	The impacts of the system on the natural environment are assessed	*Question 1*	Are the impacts of the system on land assessed?

		Question 2	Are the impacts of the system on air assessed?
		Question 3	Are the impacts of the system on water assessed?
		Question 4	Are the impacts of the system on life assessed?
Milestone 2	The impacts of the system on the built environment are assessed	*Question 1*	Are the impacts of the system on buildings assessed?
		Question 2	Are the impacts of the system on spaces assessed?
		Question 3	Are the impacts of the system on infrastructure assessed?
Milestone 3	The impacts of the system on the social environment are assessed	*Question 1*	Are the impacts of the system on social relationships assessed?
		Question 2	Are the impacts of the system on cultural milieus assessed?
		Question 3	Are the impacts of the system on institutions assessed?
		Question 4	Are the impacts of the system on immediate physical surroundings assessed?
Milestone 4	Negative impacts of the technology and its system on the natural environment are mitigated	*Question 1*	Are negative impacts of the technology and its system on land mitigated?
		Question 2	Are negative impacts of the technology and its system on air mitigated?
		Question 3	Are negative impacts of the technology and its system on water mitigated?
		Question 4	Are negative impacts of the technology and its system on life mitigated?
Milestone 5	Negative impacts of the technology and its system on the built environment are mitigated	*Question 1*	Are negative impacts of the technology and its system on buildings mitigated?
		Question 2	Are negative impacts of the technology and its system on spaces mitigated?
		Question 3	Are negative impacts of the technology and its system on infrastructure mitigated?
Milestone 6	Negative impacts of the technology and its system on social environment are mitigated	*Question 1*	Are negative impacts of the technology and its system on social relationships mitigated?

		Question 2	Are negative impacts of the technology and its system on cultural milieus mitigated?
		Question 3	Are negative impacts of the technology and its system on institutions mitigated?
		Question 4	Are negative impacts of the technology and its system on immediate physical surroundings mitigated?
Milestone 7	Impacts of the technology and its system that emerge from the demonstration phase are assessed	*Question 1*	Are any other impacts on the natural environment that have emerged from the demonstration phase been assessed?
		Question 2	Are any other impacts on the built environment that have emerged from the demonstration phase been assessed?
		Question 3	Are any other impacts on the social environment that have emerged from the demonstration phase been assessed?
	SEL 4 deployment		
Milestone 1	Negative impacts of the technology and its system that emerged from the demonstration phase are mitigated	*Question 1*	Are negative impacts on the natural environment which emerged from the demonstration phase mitigated?
		Question 2	Are negative impacts on the built environment which emerged from the demonstration phase mitigated?
		Question 3	Are negative impacts on the social environment which emerged from the demonstration phase mitigated?
Milestone 2	Harm to the natural environment is as low as possible within the limits of the project/technology	*Question 1*	Are impacts on the natural environment sufficiently mitigated?
		Question 2	Are risks or uncertainties to do harm to the natural environment in the future mitigated?
Milestone 3	Harm to built environment is as low as possible within the limits of the project/technology	*Question 1*	Are impacts on the built environment sufficiently mitigated?
		Question 2	Are risks or uncertainties to do harm to the built environment in the future mitigated?
Milestone 4	Harm to social environment is as low as possible within the limits of the project/technology	*Question 1*	Are impacts on the social environment sufficiently mitigated?

		Question 2	Are risks or uncertainties to do harm to the social environment in the future mitigated?

Dimension 2: Stakeholder involvement

	SEL 1 exploration		
Milestone 1	Basic inventory of all stakeholders in the field	*Question 1*	Are stakeholders who could be impacted by the innovation concept identified?
		Question 2	Are stakeholders who can have impact on the innovation concept identified?
Milestone 2	Insight into the societal attitude towards novel technologies in the sector	*Question 1*	Are the main knowledge, opinions, questions, concerns and perspectives that stakeholders have had so far concerning novel innovations in this or a similar sector identified?
		Question 2	Is the potential influence of (social) media on knowledge, opinions, questions and concerns of stakeholders regarding the (purpose of the) innovation identified?
	SEL 2 development		
Milestone 1	Inventory of all relevant stakeholders in the field for the technology	*Question 1*	Are stakeholders who could be impacted by the technology identified?
		Question 2	Are stakeholders who can have impact on the technology identified?
Milestone 2	Decision on level of participation of the stakeholders in development process of the innovation	*Question 1*	Are the stakeholders who are relevant for the development identified?
		Question 2	Is the – best fitting - participation level for every stakeholder determined?
		Question 3	Is the potential contribution of stakeholders to the development of the innovation identified?
Milestone 3	Design for stakeholder participation tailored to stage of development	*Question 1*	Is stakeholder participation in the development phase arranged?
		Question 2	Are stakeholders that may have positive impact on the innovation involved?
		Question 3	Are stakeholders that may have negative impact on the innovation involved?
		Question 4	Are all the stakeholders informed (taking along in the process) at the moment that benefits them the most?
Milestone 4	Knowledge, opinions, questions, concerns and perspectives of all relevant stakeholders regarding the innovation are assessed and integrated into innovation development strategy	*Question 1*	Are knowledge, opinions, questions, concerns and perspectives of stakeholders regarding the innovation (technologies, concept and stakeholders) which can hamper further development of the innovation assessed?

		Question 2	Is the influence of (social) media to the public and stakeholders perspective and attitude assessed?
		Question 3	Are actions for information providing, trust building and securing the cooperation of stakeholders and the public developed?
Milestone 5	Inventory of all relevant stakeholders in the field for the system	*Question 1*	Are stakeholders who could be impacted by the system identified?
		Question 2	Are stakeholders who can have impact on the system identified?
Milestone 6	Identification of possible trust issues for the technology and it's system	*Question 1*	Are possible trust issues for the technology identified?
		Question 2	Are possible trust issues for the system identified?
	SEL 3 demonstration		
Milestone 2	Inventory of all relevant stakeholders in the field for the technology and it's system	*Question 1*	Are stakeholders who could be impacted by the technology and its system identified?
		Question 2	Are stakeholders who can have impact on the technology and its system identified?
Milestone 3	Decision on level of participation of the stakeholders in demonstration process of the technology and it's system	*Question 1*	Are the stakeholders who are relevant for the demonstration identified?
		Question 2	Is the – best fitting - participation level for every stakeholder in the demonstration phase determined?
		Question 3	Is the potential contribution of stakeholders to the demonstration of the innovation identified?
Milestone 3	Design for stakeholder participation tailored to stage of demonstration of the technology and its system	*Question 1*	Is stakeholder participation in the demonstration phase arranged?
		Question 2	Are stakeholders who can have positive impact on the demonstration involved?
		Question 3	Are stakeholders who can have negative impact on the demonstration involved?
		Question 4	Are all the stakeholders informed (taking along in the process) at the moment that benefits them the most?

Milestone 4	Knowledge, opinions, questions, concerns and perspectives of the majority relevant stakeholders of demonstration site translated into the project design/strategy for further development.	*Question 1*	Are knowledge, opinions, questions, concerns and perspectives of the majority of the stakeholders regarding the demonstration taken into account and translated into the project design/strategy for further development of the technology and its system?
		Question 2	Is the influence of (social) media on the public and stakeholders attitude towards the innovation assessed and translated into the project design/strategy for further development of the technology and its system?
		Question 3	Are needs, concerns and values of the majority of the stakeholders taken into account and translated into the project design/strategy for further development of the technology and its system?
Milestone 5	Trust building actions are taken for demonstration of the technology and its system	*Question 1*	Are stakeholder expectations assessed?
		Question 2	Are necessary actions for information, trust building and securing the cooperation of stakeholders and the public on the demonstration site taken?
		Question 3	Are measures for information providing, trust-building and securing the cooperation of stakeholders and the public on the demonstration site taken?
		Question 4	Are the majority of relevant stakeholders acknowledged in the impact they experience?
	SEL 4 deployment		
Milestone 1	Decision on level of participation of the stakeholders in deployment process of the innovation	*Question 1*	Are the stakeholders who are relevant for the deployment identified?
		Question 2	Is the – best fitting - participation level for every stakeholder in the deployment phase determined?
		Question 3	Is the potential contribution of stakeholders to the deployment of the innovation identified?
Milestone 2	Design for Stakeholder participation tailored to deployment stage of the technology and its system	*Question 1*	Is stakeholder participation in the deployment phase arranged?
		Question 2	Are stakeholders who can have positive impact on the deployment involved?
		Question 3	Are stakeholders who can have negative impact on the deployment involved?

		Question 4	Are the majority of stakeholders informed (taking along in the process) at the moment that benefits them the most?
Milestone 3	(Deployment of) the technology and its system is supported by sufficient relevant stakeholders	*Question 1*	Are compensation or other measures at the technologies disposal to contribute to the public support?
		Question 2	Are expectations of stakeholders and the public managed well?
		Question 3	Is a (social) media strategy in place?
Milestone 4	The relevant stakeholders are included in the deployment process	*Question 1*	Are stakeholders well informed on the deployment of the technology and its system?
		Question 2	Are relevant stakeholders included in the deployment process of the technology and its system?
		Question 3	Is there a coordinated knowledge flow by the sector in place, to ensure sharing knowledge and experience between the implementors/organizations in the sector?
		Question 4	Are the stakeholders taken along in the process from the moment they could be involved?

Dimension 3: Policy and regulations

	SEL 1 exploration		
Milestone 1	The current political climate and context is explored	*Question 1*	Do you have an overview of the current political climate and context?
		Question 2	Is there security of regulatory support and policy certainty regarding innovations in similar sectors?
Milestone 2	Existing policies and regulatory framework for innovation explored	*Question 1*	Are possible relevant existing policies and regulations for the innovation explored?
		Question 2	Are relevant European, national, regional and local policies and regulations - and the way they interact - explored?
Milestone 3	Access to regulatory process	*Question 1*	Do you know which jurisdiction levels/governments are relevant?
		Question 2	Are necessary contacts made with relevant jurisdictions/governments?
Milestone 4	First interactions between developers and governments to create support for technology	*Question 1*	Are contacts established to enable collaboration with and between different departments/governments on all relevant levels for the key-system?
	SEL 2 development		
Milestone 1	Existing policies and regulatory framework for the technology assessed	*Question 1*	Are possible relevant existing policies and regulations for the technology assessed?
		Question 2	Are relevant European, national, regional and local policies and regulations - and the way they interact - assessed?
		Question 3	Is clear what is needed to embed the innovation in policy strategies? (national, regional, local)
Milestone 2	Policy and regulatory drivers and barriers are assessed for the technology	*Question 1*	If necessary - is there a regulatory push to develop and adopt the technology?
		Question 2	Are the policy and regulatory barriers assessed?
		Question 3	Are current policies sufficiently effective for further development of the technology?
		Question 4	Are needs for new policies and/or regulations assessed?

Milestone 3	Certification and permit requirements for the technology are assessed	*Question 1*	Are requirements for permits assessed for the technology?
		Question 2	Are requirements for certificates assessed for the technology?
Milestone 4	Interactions between developers and governments to secure support for the technology development are underway	*Question 1*	If necessary, is collaboration with and between different departments/governments established on all relevant levels for the key-system?
		Question 2	If necessary, is there professional lobbying through (newly established) platforms and existing interest groups in place for the key-system?
	SEL 3 demonstration		
Milestone 1	Certification and permit requirements for the system are assessed	*Question 1*	Are requirements for permits assessed for the system?
		Question 2	Are requirements for certificates assessed for the system?
		Question 3	
		Question 4	
Milestone 2	Interactions between developers and governments are in an advanced stage and have secured support for demonstration of the technology and its system	*Question 1*	Is support for the demonstration of the technology and its system secured through collaboration with and between different departments/governments.
		Question 2	If necessary, is there professional lobbying through newly established platforms and existing interest groups in place for the system?
Milestone 3	Policy and regulatory drivers and barriers are assessed for the system	*Question 1*	If necessary, is there a regulatory push to develop and adopt the technology?
		Question 2	Are the policy and regulatory barriers assessed?
		Question 3	Are current policies sufficiently effective for further development of the technology?
		Question 4	Are needs for new policies and/or regulations assessed?
		Question 5	If there are any, is there a way to avoid potential regulatory lock-inns regarding the system?

Milestone 4	Regulatory and policy framework supports demonstration of the technology and its system	*Question 1*	Is the policy and regulatory framework to support the demonstration of the technology and its system in place, either by law or by regulatory sandboxes?
		Question 2	If necessary, are available support schemes used?
		Question 3	Is the innovation embedded in policy strategies? (national, regional, local)
	SEL 4 deployment		
Milestone 1	Regulatory barriers are overcome for the technology and its system	*Question 1*	Is there the ability to pass legislation (or reduce resistance)?
		Question 2	Are regulatory barriers dealt with accordingly?
Milestone 2	Supporting policies, laws, and regulations are in place for the technology and its system	*Question 1*	Are required adjustments made to regulations? e.g. new regulations in place?
		Question 2	Does the technology and its system work in a legal sense as part of laws and regulations, standards, protocols, professional codes?
		Question 3	Are supportive policy and regulations in place for deployment of the technology and its system?
Milestone 3	Required permits and/or certificates for deployment of the technology and its system are awarded	*Question 1*	Are conditions for obtaining the required permits identified?
		Question 2	Are required permits obtained?
		Question 3	Are conditions for obtaining the required certificates identified?
		Question 4	Are required certificates obtained?
Milestone 4	(Inter)national policy and regulatory framework supports deployment of the technology and its system	*Question 1*	Is the national policy and regulatory framework to support the deployment of the technology and its system in place?
		Question 2	If necessary, is the international policy and regulatory framework to support the deployment of the technology and its system in place?
		Question 3	If necessary, are available support schemes used?

		Question 4	Is the innovation embedded in policy strategies? (national, regional, local)

Dimension 4: Market and Resources

	SEL 1 exploration		
Milestone 1	Financial resources are sufficient for exploration of the idea	*Question 1*	Is estimated what the budget needed is for funding the idea?
		Question 2	Is there sufficient budget for the exploration of the idea?
		Question 3	Is there sufficient budget for necessary R&D activities?
Milestone 2	Current market dynamics, size and potential growth are identified	*Question 1*	Are potential customers identified?
		Question 2	Are potential suppliers identified?
		Question 3	Are potential competitors identified?
		Question 4	Are current market prices identified?
Milestone 3	A market need/gap is identified	*Question 1*	Are potential customers identified?
		Question 2	Are substitutes identified?
	SEL 2 development		
Milestone 1	Financial resources are sufficient for development of the technology	*Question 1*	Are there public/private funds?
		Question 2	Is the financing for fundamental research sufficient?
		Question 3	Is the budget for the R&D activities in the development phase sufficient?
		Question 4	Are necessary and sufficient financial resources defined?
Milestone 2	Market segments, niches, size, growth and its future potential are assessed	*Question 1*	Are potential customers assessed?
		Question 2	Are potential suppliers assessed?
		Question 3	Are competitors assessed?
		Question 4	Are current market prices assessed?
Milestone 3	The market need/gap is analyzed and evaluated	*Question 1*	Is the market need/ customers need and demand assessed?

		Question 2	Are consumers' contribution(s) to the technology deployment assessed?
		Question 3	Is the significance and the role of consumers in the development and deployment of the technology in the market assessed?
		Question 4	Are substitutes assessed?
Milestone 4	A first business case is made	*Question 1*	Has a feasibility study been done?
		Question 2	Are market dynamics integrated in the business case?
		Question 3	Are the costs and benefits assessed?
		Question 4	Is potential customer value assessed?
	SEL 3 demonstration		
Milestone 1	Financial resources sufficient for demonstration of technology and it's system	*Question 1*	Is the budget for the research in the demonstration phase sufficient?
		Question 2	Are public/private funds used?
		Question 3	Are financial resources for demonstration of the whole system sufficient?
Milestone 2	Market strategy adapted to market dynamics	*Question 1*	Is the market strategy adapted to customers?
		Question 2	Is the market strategy adapted to suppliers?
		Question 3	Is the market strategy adapted to competitors?
		Question 4	Is the market strategy adapted to market prices?
Milestone 3	Business case adapted to findings for demonstration	*Question 1*	Are (private) financers identified and are they involved?
		Question 2	Is there a business plan?
		Question 3	Are costs assessed?
		Question 4	Are benefits assessed?
Milestone 4	Technology and its system adapted to market/customer needs	*Question 1*	Are customer demands integrated in the whole system?

		Question 2	Are market demands which emerge from the demonstration phase assessed?
		Question 3	Are customer demands which emerge from the demonstration phase assessed?
	SEL 4 deployment		
Milestone 1	Financial resources sufficient for deployment of technology and it's system	*Question 1*	Are public/private funds used?
		Question 2	Are financial resources sufficient for deployment of the whole system?
Milestone 2	Market ready for adoption	*Question 1*	Is there a good market position? (image, marketshare)
		Question 2	Is there a competitive advantage?
		Question 3	Is value created?
		Question 4	Are market demands integrated in the whole system?
Milestone 3	Solid business case for deployment of whole system	*Question 1*	Is there a financial model?
		Question 2	Is there a business plan?
		Question 3	Are (private) financers identified and are they involved?
		Question 4	Is customer value created?
Milestone 4	Whole system meets market/customer needs	*Question 1*	Are market needs which emerged from the demonstration phase integrated?
		Question 2	Are customer needs which emerged from the demonstration phase integrated?
		Question 3	Does the whole system meet market needs?
		Question 4	Does the whole system meet customer needs?

6.3 Examples supporting methods and tools to answer questions

Method or tool	Description/types	Reference
Market analysis tools	Examples are: observation consumer behavior, surveys (interviews, individual/telephone/social media surveys), focus groups, situation analysis (e.g. SWOT analysis and PEST analysis), market analysis reporting, competitor analysis. PEST analysis is a tool for market analysis. It takes external factors that can affect a business into account.	For more information see: https://pestleanalysis.com/market-analysis-tools/
Feasibility study approach	Assessment of practicability of the proposed technological innovation project or system, looking at the costs and benefits.	For more information see: https://www.asha.org/practice/feasibility/
Business Model Analysis	Examples are: business model canvas, business model navigator Supporting methods to describe the business model.	For more information see: https://www.lead-innovation.com/english-blog/business-model-innovation-which-method-is-right
Value Case Methodology	Method to align and get insight into the financial and non-financial values in multi-stakeholder projects	For more information see: https://www.tno.nl/en/focus-areas/strategic-analysis-policy/expertise-groups/strategic-business-analysis/value-case-methodology/
Environmental risk assessment	Evaluate the possible risks of the technological innovation on the environment. Example are the ERA methods to identify hazards, exposure, consequences and estimate risks. Other examples are the ecological risk assessment, site specific	For more information see: https://www.eea.europa.eu/publications/GH-07-97-595-EN-C2/chapter7h.html https://www.eea.europa.eu/publications/GH-07-97-595-EN-C2/chapter4h.html

	assessment, transportation risk assessment, product risk assessment.	
Regulatory impact Assessment	A method to assess the effects, either positive or negative, of proposed and existing regulations. An example is the Rapid Impact Assessment Method.	For more information see: https://www.eea.europa.eu/publications/GH-07-97-595-EN-C2/chapter7h.html https://www.oecd.org/regreform/regulatory-policy/ria.htm https://link.springer.com/content/pdf/10.1007/BF03161532.pdf
Desk research	Research method to collect information from existing resources and review the findings. Common sources are books, encyclopedias, articles, peer reviewed articles, media, policy documents, research project result reports. It is considered as a quick and cheap method to collect data, time of a researcher to do the literature analysis is the investment that is needed here for. Key search words can be determined beforehand to narrow the scope of the desk study search. Good analytical skills are required to do a good desk research. Different methods of content analysis or systematic reviewing can be employed.*12*	For more information see: https://libguides.ithaca.edu/research101/primary Schreier, Margrit. Qualitative content analysis in practice. Los Angeles: SAGE, 2012. Krippendorff, Klaus. Content analysis: an introduction to its methodology. Fourth Edition. Los Angeles: SAGE, 2018. Petticrew, Mark, und Helen Roberts. Systematic reviews in the social sciences: a practical guide. Malden, MA ; Oxford: Blackwell Pub, 2006. Mengist, Wondimagegn, Teshome Soromessa, und Gudina Legese. „Method for Conducting Systematic Literature Review and Meta-Analysis for Environmental Science Research“. MethodsX 7 (2020): 100777. https://doi.org/10.1016/j.mex.2019.100777. Bearman, Margaret, und Phillip Dawson. „Qualitative Synthesis and Systematic Review in Health Professions Education: Qualitative Synthesis and Systematic Review“. Medical Education 47, Nr. 3 (März 2013): 252–60. https://doi.org/10.1111/medu.12092.[GT(1] [SM(2]

Surveys	Collection of information by conducting surveys from stakeholders by getting responses to questions. It is a quantitative research method to collect information for different type of respondents. To collect information with surveys: design multiple survey questions, determine objective, determine target audience, select respondents, set out the survey via decided mediums (e.g. online, phone, face to face), collect sufficient response on the survey questions and analyse the results of the survey. Benefits of surveys are: minimum investment, various ways of survey response collection, anonymity respondents – confidentiality. A challenge can be to get sufficient response because of unwillingness or inability for respondents to answer survey questions. Reliability of survey results can be an issue because of differences in the understanding of questions (e.g. different interpretation of questions results in different answers). One way to minimize this risk is to incorporate cognitive interviews in the survey design.	For more information see: https://www.questionpro.com/blog/types-of-survey/ https://research-methodology.net/research-methods/survey-method/ https://www.questionpro.com/blog/types-of-survey/ https://research-methodology.net/research-methods/survey-method/ Willis, Gordon. „Cognitive Interviewing in Survey Design: State of the Science and Future Directions“. In The Palgrave Handbook of Survey Research, herausgegeben von David L. Vannette und Jon A. Krosnick, 103–7. Cham: Springer International Publishing, 2018. https://doi.org/10.1007/978-3-319-54395-6_14. https://research-methodology.net/research-methods/survey-method/

	There are different types of survey methods: cross sectional, longitudinal and retrospective survey.	
Interviews	Research method to collect information by conduction of interviews with experts and stakeholders. An interview protocol has to be designed including interview questions. Selection of interviewees has to take place, and an experienced and skilled interviewer should conduct the interviews. It is a time-consuming research method. Types of interviews: ○ Open interviews ○ Semi structured interviews ○ Structured interviews ○ Expert interviews ○ Panel interview ○ Group interview *<u>Semi-structured interviews</u>* Method to collect qualitative information on the context, the interest, perceptions, positions and perspectives of the stakeholders, the different stakeholder roles, their problems, concerns and issues they	Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C. (2009) Who's in and why? A typology of stakeholder analysis methods for natural resource management, Journal of Environmental Management 90, 1933-1949 Hermans L.M., (2005). Actor Analysis for Water Resources Management, putting the promise into practice, ISBN 90-5972-091-1, Eburon, 2005 Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement Schreier, Margrit. Qualitative content analysis in practice. Los Angeles: SAGE, 2012. Krippendorff, Klaus. Content analysis: an introduction to its methodology. Fourth Edition. Los Angeles: SAGE, 2018.

	have and challenges they see. A way to get a good understanding of the different stakeholders and who to select for further stakeholder engagement and involvement. It can be used when there are conflicting interests of stakeholders. The semi-structured interview questions need to be developed based on specific topics and the objective of the interview. An interview protocol needs to be designed, the interviewees need to be selected and invited for an interview. Interviews can be conducted by phone, online or face to face. Interview voice recordings, interview reports or transcripts have to be made. An analysis of interview results is necessary (often through methods of content analysis). An experienced and skilled interviewer has to conduct the interview. It is a time-consuming method (for interviewer and interviewees), hence costly.	

Participant observation	Participant observation is a qualitative research method that can be applied in various ways to develop a holistic understanding of situations, practices and interactions. It can be used to observe events self-organized by stakeholders (e. g. events opposing the introduction of an innovation), gain detailed insights in the context specific interactions of stakeholders with innovations in the demonstration stage and thereby provide valuable input for other methods (for instance for survey or interview designs) or help to validate information gathered with other methods (e. g. opinions studied by surveys).	Kawulich, Barbara B. „Participant Observation as a Data Collection Method“. Forum Qualitative Sozialforschung / Forum: Qualitative Social Research 6, Nr. 2 (31. Mai 2005). https://doi.org/10.17169/fqs-6.2.466.
Stakeholder analysis	There are many methodologies and tools for conducting stakeholder analyses: for the identification of stakeholders, to differentiate between and categorize stakeholders and to identify relationships between stakeholders.	Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H. and Stringer, L.C. (2009) Who's in and why? A typology of stakeholder analysis methods for natural resource management, Journal of Environmental Management 90, 1933-1949 Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement

	Methods and tools for the identification of stakeholders: • Brainstorm session (focus groups) • Semi-structured interviews • Snowball mapping Methods and tools to differentiate between and categorize stakeholders: • Interest-influence matrices • Radical transactiveness • Stakeholder led categorization • Q-method • Salience method Methods and tools to identify relationships between stakeholders: • Actor-linkage matrices • Social network analysis • Knowledge mapping • Institutional analysis	
Stakeholder analysis method - Brainstorm Session/Focus Groups	Brainstorm and Focus group – method - to collect qualitative and quantitative data through group interaction on a particular topic.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement

Stakeholder analysis method - Snow-ball mapping	Approach to develop a more complete overview of the stakeholder field, supporting the stakeholder selection process.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Stakeholder analysis method - Radical transactiveness	Radical Transactiveness (RT) is a concept to identify, explore and integrate stakeholders' views that are radical, that might otherwise be neglected. For example, stakeholders that are: not interested, not legitimate, not human, isolated. It is a dynamic capacity to identify 'not powerful' stakeholders by snow-ball mapping. It is a time-consuming approach.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Stakeholder analysis method - Q methodology	Q-methodology analyses stakeholders' views and perspectives based on sample statements on a specific topic. These statements are ranked by the stakeholders' individually. This provides insight in the different viewpoints and stakeholders' profile. The method allows for identification of social discourses and the categorisation of stakeholders.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Stakeholder analysis method - Salience model	The salience model to identify the stakeholders that need to be directly involved in a	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of

	participatory process by scoring types of stakeholders. The stakeholders are scored on: legitimacy, urgency and power. It is a simple method to use and not time consuming to position stakeholders. A deep understanding of stakeholders' interests is not reached hereby.	Stakeholder Analysis and Involvement
Stakeholder analysis method - Influence matrices	"Influence matrices" is a method to get insight in the power dynamics of stakeholders. Stakeholders are positioned within a matrix on a scale of level of influence, interest or importance. The information on the stakeholders' power dynamics is a basis for strategy development for stakeholder involvement. It does not provide information on the stakeholders' perspectives, views, issues, roles, etc. It is an easy and fast method to use. Stakeholders can be positioned within the matrix by: by a single person (e.g. expert, researcher) or the	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement

	stakeholders themselves. Knowledge on the stakeholder field and relative position is crucial here for. Feedback on the outcome by experts in the field is advised.	
Stakeholder analysis method - Stakeholder-led categorisation	A Stakeholder-led categorisation is a method that stakeholders themselves create categories and position also the other stakeholders within categories. Be aware that this is based on the perceptions of the stakeholders, and what the meaning is of the categorisation and positioning.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Stakeholder analysis method - Social network analysis	A social network analysis (SNA) is a method to map and measure relationships and links between people and organisations. The purpose is to get insight in the network of stakeholders and their relations. This information is collected by structured interviews or questionnaires.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Stakeholder analysis method - Knowledge mapping	Knowledge mapping is a method for the identification of links and knowledge between stakeholders. This method makes use of semi-structured interviews and is used in	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement

	combination of the social network analysis method. It provides insight in the stakeholders working well together and the power balance.	
Stakeholder analysis method - Institutional analysis	Institutional analysis provides insight in the institutional arrangements and settings of a particular topic that influence the stakeholders and their relationships. For example the formal and informal rules of society and rules influencing policy. Empirical tools and methods can support the institutional analysis, to identify, describe and assess institutional arrangements. Complimentary to this method are: interviews of stakeholders, focus groups, workshops, and surveys. This analysis is resource intensive and skills and expertise are required (e.g. institutional knowledge, knowledge about relevant legislation, but also norms and other informal rules).	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Visualization tools stakeholder analysis	Stakeholder analysis visualization tools to present the outcome, examples are: - *Venn Diagrams* show the relationships between	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement

	stakeholders, - *Spider Diagrams* to show the capacity of a stakeholder organisation. - *Matrices*, to show stakeholders categorization, for instance by influence and power, or interest and trust.	
Stakeholder tracking tools	Logbook and Factsheets to keep track of stakeholders and relevant information during development of an innovation. For example keep track of key stakeholders, roles, perspectives, issues, power dynamics, relations, etc.	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Stakeholder involvement and engagement approaches	Stakeholder involvement and engagement approaches are: • Mutual Gains Approach (MGA) • Rebuild By Design • Participation Ladder • Capacity Building (CAP4PE).	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement

Knowledge brokering instruments	For developing knowledge jointly with stakeholders and sharing knowledge, connecting knowledge to policy and to practice, knowledge brokerage instruments can be used. Knowledge brokering instruments are: - Scenario development - Group model building - Role playing - Communities of practice/Network of practice	Geerdink, T., Willems, R., Botteman, M., Schellekens, E., Knapp, B., Schwingenschloegl, C., (2015). D6.1 Actor Analysis RESIN Actor Analysis for Urban Climate Adaptation Methods and Tools in support of Stakeholder Analysis and Involvement
Environmental impact assessment	A procedure to ensure that implications on the environment are taken into account before decisions are made. Can be used for individual projects as well as for public plans or programmes. It ensures that projects which are likely to impact the environment are assessed before they are approved or authorized.	Glasson, J., & Therivel, R. (2013). Introduction to environmental impact assessment. Routledge. https://ec.europa.eu/environment/eia/index_en.htm

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