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HÖRDUR HARALDSSON AND DANIEL BONIN

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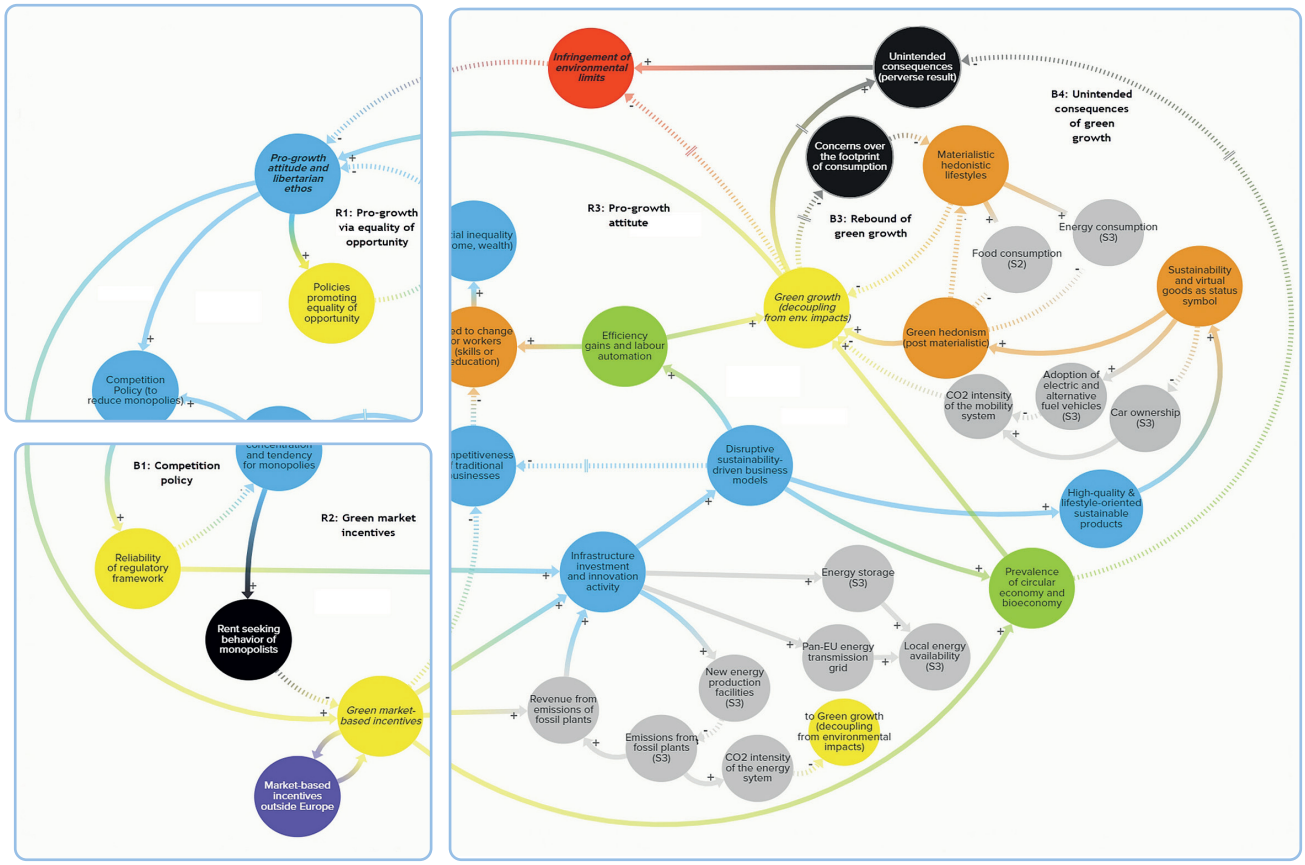

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Preface

The Swedish Environmental Protection Agency (Swedish EPA) takes part in the European Environment Information and Observation Network (EIONET) which is a partnership network of the European Environment Agency (EEA) and its 38 member and cooperating countries. EIONET includes National Reference Centres (NRC), The NRC on Forward-looking information and services (FLIS) is one of these.

This project draws upon results of the project NRC FLIS Scenarios for a Sustainable Europe in 2050 (SSE 2050). This project is an approach to abridging the foresight *Scenario Method* with the *system dynamic qualitative approach* using the *Causal Loop Diagramming* method. Systems dynamics is the operational part of *systems thinking* (also described as *systems approach* or *systems analysis*) to understand and predict the dynamic behaviour of defined systems under study. The main project (part 1) Scenarios for a Sustainable Europe in 2050 was developed by Germany's central environmental authority (UBA Germany) and the EEA (both lead), with input from the Swedish EPA and the Netherlands Environmental Assessment Agency (PBL Netherlands). This project (part 2) was developed by the Swedish EPA (Hördur Haraldsson) with input from UBA Germany and PBL Netherlands. Z_punkt The Foresight Company, a leading international firm for corporate and public foresight, supported with project facilitation. The project was carried out and facilitated in several closed sessions by Daniel Bonin (Z_punkt) and Hördur Haraldsson, with valuable feedback from Ullrich Lorenz (UBA Germany), Ed Dammers (PBL Netherlands) and Mike Asquith (EEA).

Hördur Haraldsson has been the project manager for this report and provided the methodological expertise on system dynamic modelling and CLD loop analysis, and Daniel Bonin from Z_punkt provided methodological expertise on the foresight *Scenario Method* analysis and documented the CLD process in the Kumu.

Stockholm, March 2021

Maria Ohlman
Head of Sustainable Development Department

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1. Summary

The main purpose of this study was to showcase the use of Causal Loop Diagrams (CLD) analysis of the scenarios developed in the EIONET NRC FLIS project Scenarios for a Sustainable Europe in 2050 (SSE 2050). This study attempts to abridging the foresight *Scenario Method* with the *system dynamic qualitative approach* using the *Causal Loop Diagramming* method. In the study, the four narratives *(Ecotopia, A Pragmatic Path, Green Growth Paradigm, Utilitarian Technocracy for Good)* from the SSE 2050 project were interpreted and contextualized to develop the CLDs. Combining the results of the Scenario Method from SSE 2050 with systems dynamics modelling was a special feature of this project.

The overall goal of the project was to 1) Show how scenario narratives can be illustrated using feedback loops and driving forces to show the evolution of different key factors over time. 2) Analyze and enhance the plausibility of each scenario as a function of time and improve the scenario consistency by enriching the scenarios. 3) Show how systemic change can be facilitated in the normative scenarios being studied.

The results indicate that the solution scenarios produced from the SSE 2050 vary slightly in how the framing of system boundaries and the point of departure in the narratives are treated. Furthermore, the CLD can either be generic or specific in describing the scenario. All the solution scenarios required support factors to show barriers/limitations to have the CLDs work in terms of appropriate reinforcing and balancing behaviour. The solution scenarios tended to highlight reinforcing behaviour in the narratives and omit the description of limiting factors, therefore showing unlimited growth. This illustrates the difference between the Scenario Method and the CLD approach.

One of the conclusions from the study points toward the necessity to be explicit in the description of the solution scenarios (and its supporting projection description) since the factors derived for the CLDs need explicit language. This will aid in enriching and identifying key factors of influence in the scenarios, and furthermore validating and preparing the results for further communication is the next step. The study shows that scenario CLDs can be a point of departure to enrich the scenarios further and complement a foresight process.

2. Introduction

The main purpose of this study was to showcase the use of Causal Loop Diagrams (CLD) analysis of the scenarios developed in the project *Scenarios for a Sustainable Europe in 2050* (SSE 2050).[1] The CLD analysis draws upon the main results of the project SSE 2050 (EEA/EIONET NRC FLIS, 2020; EEA/Eionet NRC FLIS, project in progress). The scenario narratives developed in the project SSE 2050 are imaginative qualitative descriptions of possible futures and not based on quantitative assessments. In this study, the narratives from the SSE 2050 project were interpreted and contextualised by the authors to develop the CLDs. The CLDs are therefore based upon a set of assumptions and limitations derived from the authors. This study uses the systems approach to integrate CLD modelling analysis in the project SSE 2050 and is therefore a qualitative modelling exercise.

The overall goal of the project was to:

1. Show how scenario narratives can be illustrated using feedback loops and driving forces to show the evolution of different key factors over time.
2. Analyse and enhance the plausibility of each scenario as a function of time and improve the scenario consistency by enriching the scenarios.
3. Show how systemic change can be facilitated in the normative scenarios being studied.

Combining the results of the *Scenario Method* from SSE 2050 with systems dynamics modelling was a special feature of this project. The *Scenario Method* is an established tool in the context of foresight analysis, which aims to broaden the perspective on different possible future developments. The goal of Foresight is to support decision-making by systematically analysing plausible and possible futures and in some contexts also normative, preferable, futures. By doing so, Foresight helps with systemic transformations and to cope with a world that is increasingly perceived as highly volatile, uncertain, complex and ambiguous. Policymakers are turning to foresight methods, for instance, the European Commission recently published its first annual Strategic Foresight report (European Commission, 2020, 2019). The Scenario Method has seen evolution and application in numerous studies for the private and public sector (Deutsche Post, 2012; Lorenz and Veenhoff, 2013; Schnurr *et al.*, 2018; SDC, 2019). Scenarios are about developing different, alternative futures. The goal of scenarios in foresight projects is not to make predictions or show the most likely outcome. In the context of foresight projects, also other methods and techniques like environmental scanning, trend analysis, the Futures Wheel, Causal Layered Analysis or Delphi method can be applied to explore future developments e.g. (Millenium Project, n.d.; UNDP, 2018)

This study shows that a CLD analysis can be performed on the results coming out from the *Scenario Method*. The qualitative system dynamics uses the Causal Loop

[1] The project SSE 2050 and the developed scenarios will be enriched during 2021. This project here is based on the first results from the year 2020.

Diagramming and behaviour over time (BOT) as the primary method of describing cause and effect and feedback-loops to assess the direction of the potential impact of an explorative or normative scenario in a non-numerical way (see (Binder et al., 2004; Burns and Musa, 2001; Haraldsson, 2004; Haraldsson and Ólafsdóttir, 2018; Haraldsson and Sverdrup, 2021; Kim and Senge, 1994; Lorenz and Haraldsson, 2014; Maani and Cavana, 2007)). In the context of this study, CLDs are used as a tool to frame boundaries around each scenario and to convey the core feedback loop description of that scenario. Furthermore, each scenario was analysed to observe possible implications of feedback loop behaviour over time of the key factors under observation. This approach was pioneered by the Swedish EPA during the work on the State of the Environment reporting 2015 (Haraldsson and Wiktorsson, 2014; Haraldsson, 2020).

2.1. Introduction to scenario narratives

In the project SSE 2050 different types of scenarios narratives were developed: *a) solution scenarios*, i.e. normative scenarios that describe a desirable future of a sustainable Europe in 2050 and *b) context scenarios*, i.e. scenarios that describe the world outside Europe in 2050. Four *solution scenarios* were developed during the project SSE 2050:

- **Ecotopia**: Post-growth collaboration
- **A Pragmatic Path**: Transformation within planetary and regulatory limits
- **Green Growth Paradigm**: The great decoupling of growth in free markets
- **Utilitarian Technocracy for Good**: Society is steered towards sustainability

The narratives of the solution scenarios were used to develop a CLD for each scenario. In this study, these will be called scenario CLDs.

An important success factor was to get a common understanding of the approach and mindset of depicting the scenarios (section 2.2). The point of departure, the framing of the analysis, is the scaling as shown in Figure 1. Proper identification of scaling is important since it helps place the scenario narratives in time and space, i.e. what systems interact beneath and what interact above, i.e. the world context (context scenarios). In terms of SSE 2050, this is EU being influenced internally by its different actors on a meta-level, and external influence in the form of driving forces that act on a global level. The focus of this study is on the systemic behaviour of the scenarios SSE 2050. The scenario CLDs are intended to provide a basic understanding of the framed scenario narrative and not all aspects of what is above or beneath (system levels). However, there was an interest to look specifically upon how the scenarios connected to basic modules (see Annex), i.e., the energy, food or mobility sector, Figure 1. While the “size”, i.e. level of detail of basic modules factors are considered constant, the inner structure of these subsystems will evolve over time as an integrated system, thus influencing the evolution of the scenario. A fundamentally different future would go along with basic modules that look different from today’s perspective: the components that

make up for their system structure and interactions would change (indicated by semi-transparent shapes for basic modules and sustainability indicators).

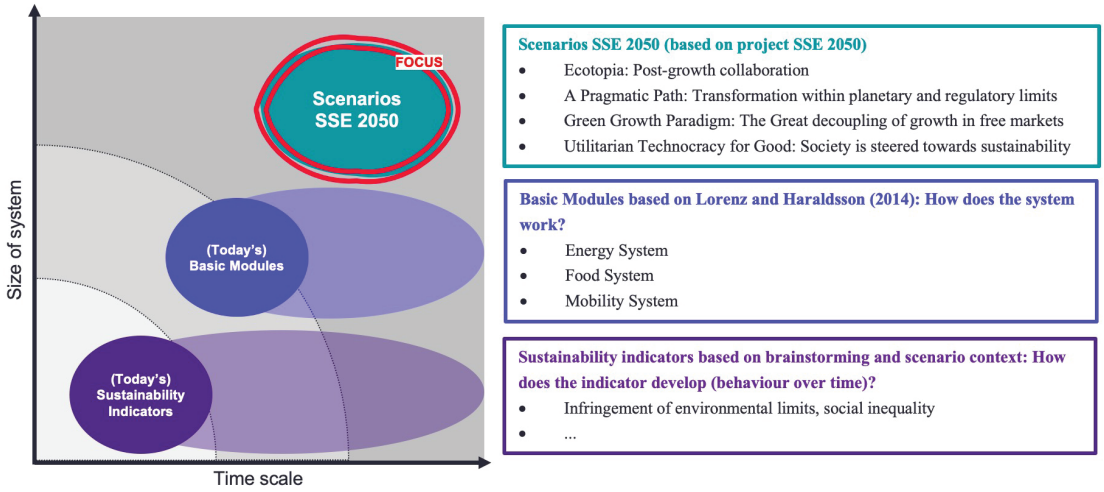

Figure 1: Focus of the project seen through system levels (scenarios, basic modules, indicators).

Chapter 3 Scenario CLDs, provides a screenshot of each scenario CLD and a short description. Furthermore, key insights and suggestions for further discussions with respect to the scenario CLD, production-consumption systems (i.e. basic modules) and elements of sustainability are presented in chapter 3. In addition to the report, the scenario CLDs can be accessed via the web-based tool Kumu and users can interact with the CLDs.

Chapter 4 Conclusions provides an overview of how the CLDs can be used in the context of SSE 2050. Chapter 4 also shows more generally the potential of how CLDs and scenarios complement each other.

2.2. Methodological approach

Qualitative modelling is an approximate science and should be treated as outcomes that interpret the narrative from a set of assumptions. When developing CLDs a key success factor is to find the appropriate level of detail that address the questions posed. A challenge in this project was to convey the story of the scenario narratives as understood from its basic description in SSE 2050 and capture the projections that supported the narratives. The approach adopted in the study was based on the KISS (keep it simple, straightforward) principle (Figure 2). For instance, this means that the number of elements per scenario should be limited to about 15 to 20 in order to maintain overview and coherence (Haraldsson, 2004). However, sometimes it greatly aids understanding if the number of elements is increased; this does not necessarily mean a growing number of loops but to understand how a collection of items can be collapsed into a single simplified factor to maintain an overview. Keeping the KISS principle in mind greatly helped to manage the process.

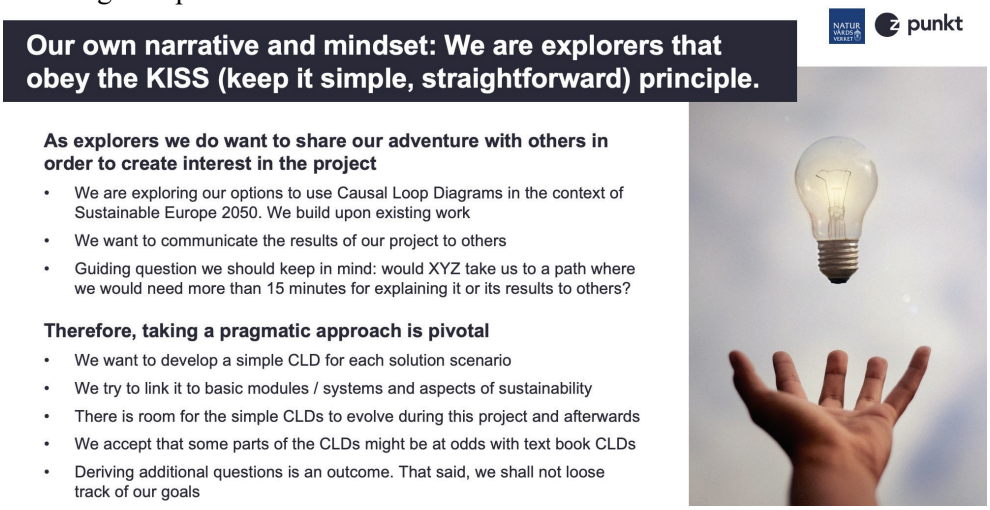

Figure 2: Mindset and narrative of the project

Combing the two different perspectives, expertise in system dynamics and CLDs (SEPA) and expertise in foresight methods (Z_punkt) allowed for overlapping complementary modes of thinking and tools to reduce complexity. Thus, combining the two approaches allowed leverage synergies between the project participants and showed where overlap enhanced the understanding of developing proper framing of the scenarios and CLDs (Figure 3). In short, Foresight points to the direction where the proper framing should occur in space and time, and systems dynamics sets the rules on how the framing should be done in respect of space and time.

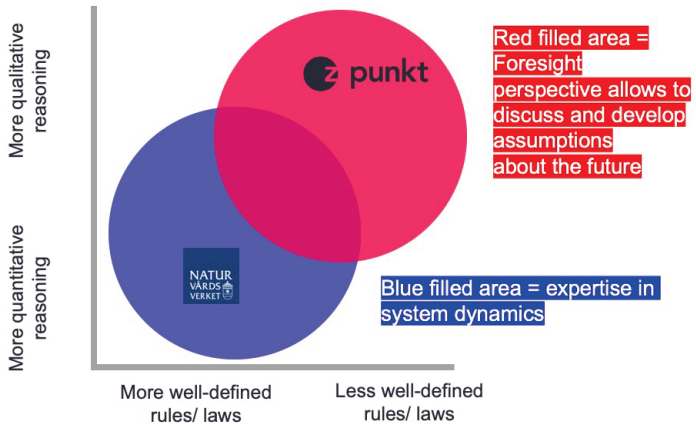

Figure 3: Foresight shows in what direction the framing should occur and system dynamics set the rules on how the framing should be done in space and time.

2.3. Work process

There are two approaches to conduct a qualitative modelling, an explorative and a descriptive approach (Abdelbari and Shafi, 2017; Barlas, 1996; Neumann, 2015). The main difference between the two approaches is the nature of dealing with boundary definitions and constructing feedbacks. The descriptive approach is focused on constructing loops and keeping track of observing combined loop behaviour with an initial question as a focus. The explorative approach focuses on identifying link structure between factors where loops evolve through the process and questions arise along the way that are interesting to the task. Both processes have its usefulness in a CLD analysis but combining the methods can give a good balance between understanding a non-structured task and pre-defined questions that set the boundary conditions for the analysis (Haraldsson, 2020; Haraldsson and Ólafsdóttir, 2018; Lorenz and Haraldsson, 2014).

The type of outcome coming from SSE 2050 project saw the use of the combined (explorative and descriptive) approach useful. This is because scenario narratives are framed with a set of conditions that "tell the story" of the situation picture in the distance future. However, the narratives do not contain specific, detailed indicators that reflect the objectives of the scenario nor how success is defined in terms of obtaining or maintaining the conditions being described. Here the combined CLD approach explores the framing of the boundaries and descriptively identifying specific success and limiting feedback parameters that influence the scenario evolution. During the project workshops it was found that this combination stimulated creative thinking with respect to different questions posed for the scenarios [2]:

- How can scenarios be framed without losing the information in the narrative description and be represented in a simplified CLD?

[2] The project did focus on developing a CLD for each scenario (first question). The other questions were raised during short virtual work meetings (about 90 minutes each). The results presented in the following chapters are to be understood as non-exhaustive. Chapter 3 shows next steps, potential follow-up activities that may be conducted to gain a better understanding about each scenario.

- What are the important cause and effect relationships and feedback-loops identified?
- What are the success and limiting factors that enable the scenario in its current form?
- What items need to be added to enable continuity/plausibility of the scenario?
- What dynamic behaviour does the scenario express when analysing loop behaviour over time?
- How does energy, food and mobility connect to each scenario, do they point to new paradigms for production-consumption systems?

The *Scenario Method* applied by Z_punkt has defined its methodological steps with a combination of methods where the impact-uncertainty analysis, consistency analysis and morphological box is combined into one process (Deutsche Post, 2012; Schnurr *et al.*, 2018; SDC, 2019). Scenarios development may focus on a specific focal topic and in the context of SSE 2050, it is sustainability. The scenarios SSE 2050 are not intended to provide an extensive description of Europe in 2050 but provide a broad frame of reference on how a room of manoeuvre of sustainability looks like under different solutions. This results in two important aspects that had been considered for developing the scenario CLDs:

a) there is no in-depth knowledge about every possible aspect for each solution scenario and
b) the short narratives focus on describing solution space in desirable futures rather than challenges that have been overcome within each scenario.

A structured participatory exchange between the project members was used involving brainstorming based on the existing scenario narratives and key factors. Kumu was used to develop the CLDs. Kumu allowed the project members to develop the CLDs collaboratively with its near real-time feature. Besides the extensive options to decorate elements and connections and functionality to highlight certain areas of the CLD, users can add additional information to elements and connections if deemed necessary. An overview of each scenario CLD developed in Kumu and a brief description and points of discussion are described in Chapter 3. The scenarios SSE 2050 will be enriched further over the next months. Based on further elaboration, the scenario CLDs developed here may be updated.

The process of developing the scenario CLDs follows the method described in (Haraldsson and Sverdrup, 2021) but adapting for this project can be broken down into three major steps (Figure 4). The framing of the scenarios already provided the system boundaries and issue definition where the items of interest could be extracted. As discussed earlier, the scenario process does not focus upon defining what aspects within each scenario create the condition for its existence. Therefore, in the CLD process, a guiding question for defining the main actors and what defines the overall success for the scenario was necessary. Furthermore, asking guiding questions on what feedback-loops and driving forces “drive” the scenario,

as well, what the opportunities and limiting factors maintaining the existence of each scenario. Each step was summarised by guiding questions. After the scenario CLD had been developed, the narrative overall impression was assessed and a behaviour over time (BOT) graph was developed for selected elements of the CLDs. The analytical process of developing the BOT was divided into four steps as shown in (Figure 5) and uses the method as described in (Haraldsson, 2004; Haraldsson and Ólafsdóttir, 2018; Haraldsson and Sverdrup, 2021). The BOT development process ultimately illustrates what feedback cycles are interesting over time and consequently the archetypical behaviour or the scenario. While developing CLDs based on the scenario narratives, it was possible to explore additional questions relating to what exists outside the narratives, i.e. impact of global drivers and interaction of subsystems. The questions posed were:

- What links can be identified between the scenario CLDs to basic modules for production-consumption systems (e.g. mobility, food, energy)?
- What links can be identified between the scenario CLDs to general aspects of sustainability of Europe and the global context?

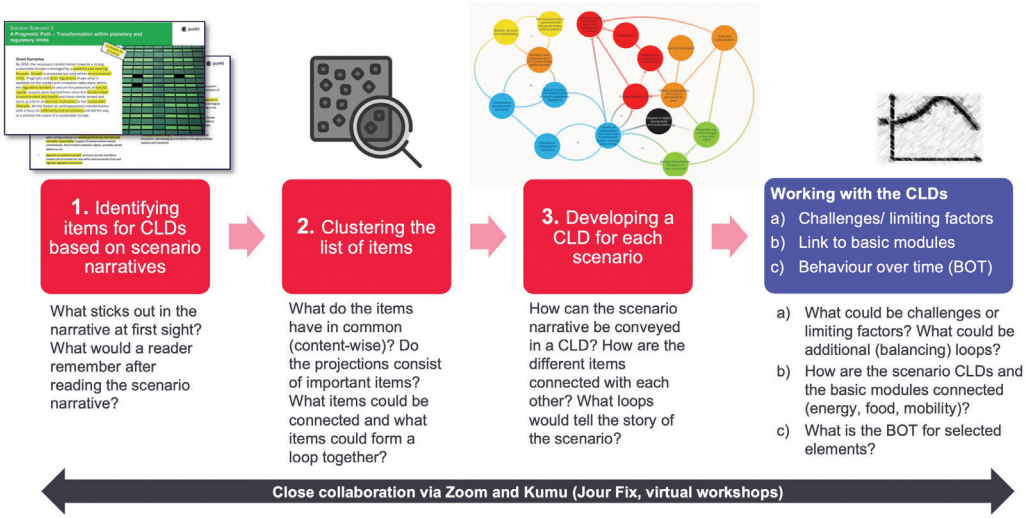

Figure 4: Overview of the three-step process for the study.

Step 1: Identifying important items based on the scenario narrative

- Guiding question(s): What sticks out in the narrative at first sight? What would a reader remember after reading the scenario narrative? What is defined as success in the narrative? For instance, success in each narrative is the story of what is being maintained as a desired state, e.g. no/low environmental infringement, high degree of efficiency etc.
- A list of items was extracted from the description of the solution scenario. Items may be single nouns, a combination of an adjective and noun or also a half-sentence. The list of items constitutes a starting basis for developing causality links between items and the start of building loops for the scenario CLDs. The process is inherently iterative, and it was understood that the CLDs would evolve during the process.

Step 2: Clustering the list of items

- Guiding question(s): What do the items have in common (content-wise) in relation to what is defined as success? What items could be connected and what items could form a loop together?
- By sorting and clustering the list of items, finding topics and umbrella terms, the number of items can be greatly reduced. Based on the list of items this process step was directly carried out in Kumu. Afterwards, the key factors and projections of the solution scenarios were used to identify additional items and connections. It is not mandatory to include all projections.[3] The goal is to have a narrower set of items that can be used to develop the CLDs.

Step 3: Developing scenario CLDs (one per scenario)

- Guiding question(s): How can the scenario narrative be conveyed in a CLD? How are the different items connected with each other and in relation to the defined success of the scenario? What loops would tell the story of the scenario?
- The different clustered items provide the starting basis to construct a scenario CLD. For this step, it is important to keep the KISS principle in mind. At this stage, items may be renamed, or additional items may be added to construct loops and to aid comprehensibility. When there is a fit, items are connected, and their polarity is defined. It is not mandatory to include all items on the list or to show every connection. Above all, a scenario CLD should reflect the core idea of the scenario with a limited number of items and a sufficient number of loops.

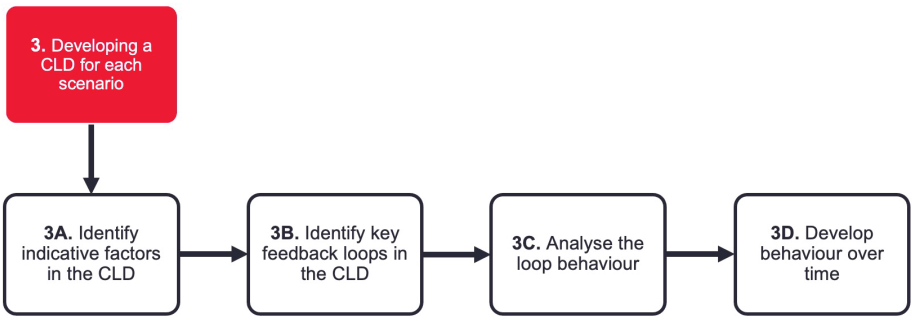

Figure 5: Analytical process of developing loop behaviour over time

Once the CLD is completed, the "core" story of the scenario is expressed through behaviour over time (BOT):
3A) indicative factors from the CLD are chosen which are intended to communicate the story through the CLD. 3B) main feedback loops (reinforcing and balancing) that drive the core behaviour of the indicative factors in the CLD are identified. 3C) loops are analysed as combined reinforcing and balancing

[3] [3] In the scenario method, key factors can be defined as follows: Key factors have a great impact on the focal topics (here: Sustainable Europe in 2050) and have a high degree of uncertainty. Due to the high degree of uncertainty, different possible projections are possible. Projections describe different states of a key factor can in 2050.

behaviour and drawn as cyclic behaviour. 3D) behaviour over time is drawn as repeated cyclic intervals of the indicative factors.

2.2 Working with the scenario CLDs

Different options of working with the scenario CLDs were explored during short virtual work meetings:

a) Identifying challenges and limiting factors

- Guiding question(s): What can be identified as challenges or limiting factors (elements)? What could be additional loops?
- The solution scenarios SSE 2050 describe desirable futures. Therefore, due to the narrative description, the CLDs have tendencies to show an excess of reinforcing loops that work towards a sustainable Europe and less of what constitute limiting factors. In this process, it was necessary to identify the limiting factors that "balance out" the reinforcing loops. Generically in the CLD development process, it is common initially to identify only the reinforcing loops since the balancing loops are often not obvious to identify. In the systems approach the reinforcing loops are a temporary state and balancings loop ultimately regulate the system. All CLDs need to illustrate how the system is regulated through reinforcing and balancing factors. In this case, it was needed to identify and insert regulating factors that would make the scenario narrative logically work. During the project, it became evident that it is not possible nor desirable to show all possible challenges and limiting factors in the CLD as this would increase the complexity too much, but the necessary aggregation was assessed in order to challenges and limiting factors. The results point to policy levers given that the solution scenarios constitute desirable futures for Europe in 2050.

b) Connecting scenario CLDs to basic modules

- Guiding question(s): How are the scenario CLDs and the basic modules connected (energy, food, mobility)?
- The development of the CLDs identified where basic modules for energy, food and mobility should be connected. During different virtual sessions of 90 minutes per scenario, it was exemplary shown that it is possible to connect the scenario CLDs via entry points with production-consumption systems (food, energy, mobility). The presented connections in the CLDs are non-exhaustive. The basic modules and their structure were taken from previous projects (Lorenz and Haraldsson, 2014). It was not within the project scope to develop new basic modules.

c) Showing the behaviour over time

- Guiding question(s): What loop behaviour creates the behaviour over time and what are the selected elements representing the scenario evolution?
- Based on the scenario CLDs, balancing and reinforcing loops are used to show the behaviour over time for selected elements. Selected elements make up for important aspects of the scenario narrative and the CLD. Elements may also describe aspects of sustainability (e.g. infringement of environmental limits).

3. Results - Scenario CLDs

Chapter 3 presents the results from the scenario CLDs developed during the project. The CLDs are based on the four solution scenarios developed during the project SSE 2050 (see Annex 6.1):

- **Ecotopia:** Post-growth collaboration
- **A Pragmatic Path:** Transformation within planetary and regulatory limits
- **Green Growth Paradigm:** The great decoupling of growth in free markets
- **Utilitarian Technocracy for Good:** Society is steered towards sustainability

The constructing of a CLD follows a specific structure where cause and effect are variables that either change in the same direction (indicated with a "plus") or change in the opposite direction (indicated with a "minus"). Processes that feedback in the same direction is called reinforced processes (indicated with R) since they amplify the condition. Similarly, the processes that feedback to give a change in the opposite direction (indicated with B) balance (dampen) out a condition (Haraldsson, 2004). Part of framing the system boundaries for the SSE 2050 solution scenarios into CLDs was analyzing the key factors as categorized according to the STEEP logic[4]. Each of the scenario narratives was initially derived based on these key factor projections during the project SSE 2050.

The scenario CLDs follow a similar structure (Figure 6). The report focuses on the most important parts of each CLD. Four types of elements (E) and two types of connections (>) are depicted in scenario CLDs:

- Parts of the scenario narrative and key factor projections (colours of the circles according to STEEP)
- Challenges, barriers and limits identified during workshops (black circles)
- First ideas for links to production consumptions systems (energy, food, mobility) are indicated (grey circles).
- First ideas for links to the context scenarios are indicated (purple circles)
- In Kumu, the graphical expression given is as follow (figure 6). A positive polarity (+) indicates that more of "A" goes along with more of "B" (solid line). For a negative polarity (-) it holds that the more of "A" the less of "B" (dashed line). Major balancing loops and reinforcing loops are indicated in each scenario CLD.

[4] STEEP is an acronym describing different sectors: society, technology, economy, ecology, politics

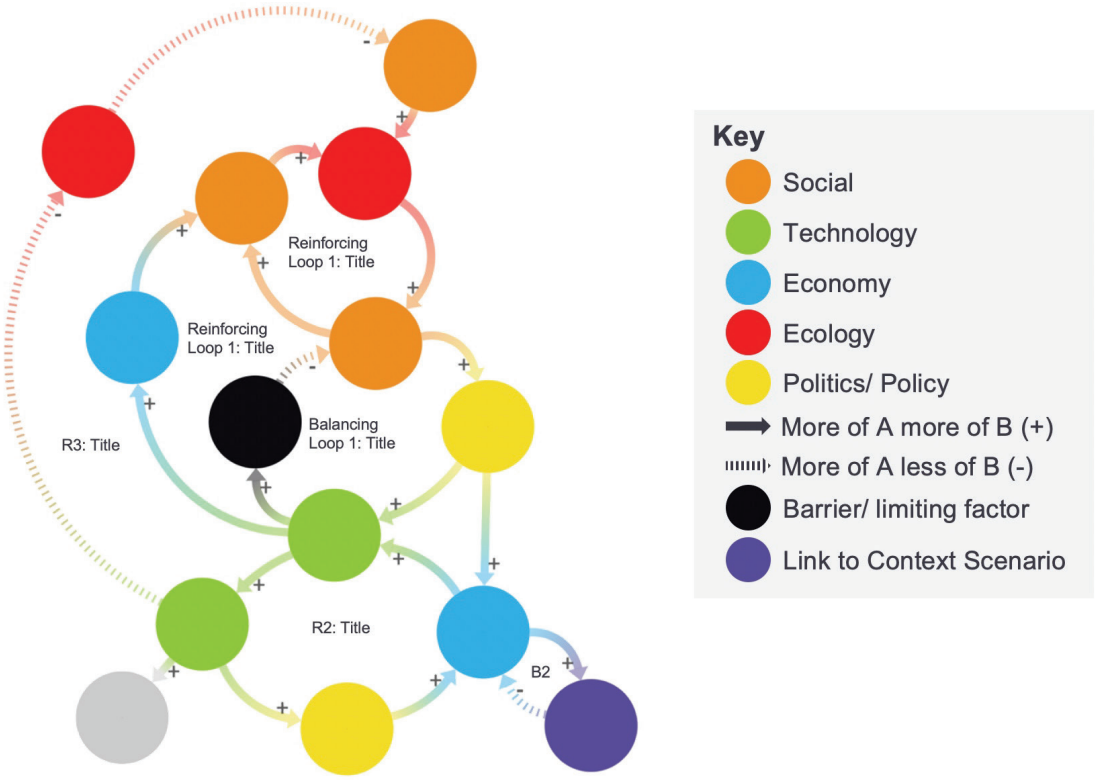

Figure 6: Schematic overview of the scenario CLDs setup and categorisation according to STEEP and system boundary definition.

Each scenario is presented in a separate section. The major characteristics of each scenario CLD are summarised. The behaviour over time (BOT) is shown in a diagram for selected elements of the CLDs and described briefly.

3.1. Utilitarian Technocracy for Good: Society is steered towards sustainability

The following CLD in figure 7, shows the result from the work process developing CLD for the solution scenario "Utilitarian Technocracy for good: Society is steered towards sustainability".

Figure 7: Scenario CLD: Utilitarian Technocracy for Good: Society is steered towards sustainability.

The solution scenario *Utilitarian Technocracy for Good* can be summed up as support for central planning and data-driven self-optimisation reduces infringement on environmental limits at the cost of personal freedom. In a short, the scenario CLD and the insights gained can be summarised as follows:

- Power of central planners is reinforced by the quality and adoption of digital infrastructures and services.
- The balancing effect of reduction in personal freedom on the power of central planners is not strong enough to keep central planners in check.

- Infringement of environmental limits declines at the price of personal freedom (see also behaviour over time shown in Figure 8).
- Quantified self-consumption, a data-driven recommendation regarding behaviour, is driving down infringement of environmental limits rather than sustainable lifestyles themselves.

Developing the CLD for the scenario *Utilitarian Technocracy for Good: Society is steered towards sustainability* made additional questions and challenges explicit that could aid the enrichment of the scenario:

- Can the decline in personal freedom be prevented? What are possible actions to reconcile personal freedom with environmental sustainability in this scenario?
- How does data-driven self-optimisation change the trade-off of consumers? Are prices still an important driver for the production-consumption systems?
- How would the concentration of power outside Europe influence the scenario (link to the context scenario, i.e. the future outside Europe)? Non-European actors might have their own agenda that is supported or undermined by this scenario.
- What if the infrastructure behind data-driven self-optimisation would stop working or is not developed timely? How would the behaviour over time change?

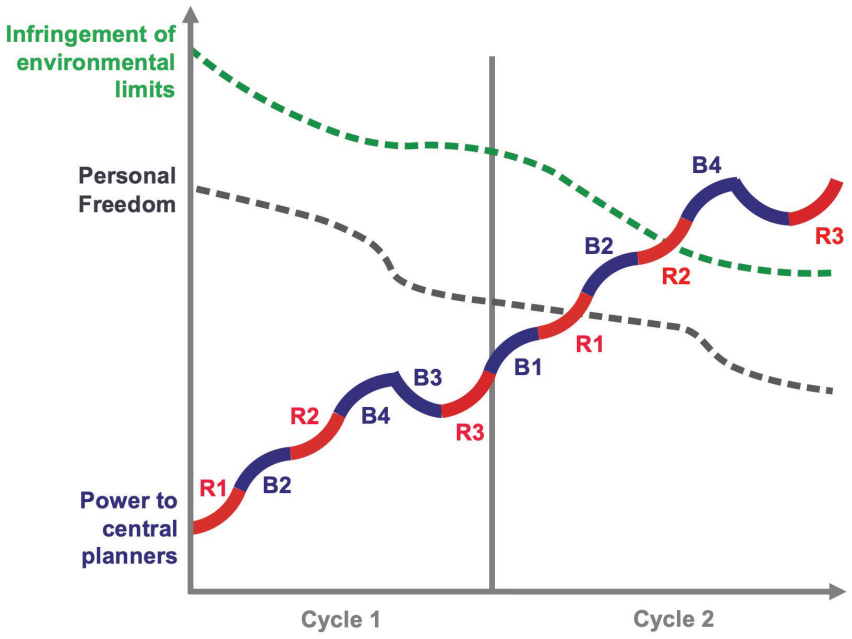

Figure 8: Behaviour over time diagram: Utilitarian Technocracy for Good: Society is steered towards sustainability.

Utilitarian Technocracy for Good: Telling the story of the scenario CLD

The scenario assumes that the frustration with libertarian governments is based on social inequalities. In this scenario, technocracy provides an alternative solution

approach to address the issue of social inequalities. Therefore, in the beginning, social inequality increases the support for technocracy and utilitarian planning and finally leads to increased power to central planners. With growing power, central planners can funnel state investment in digital infrastructure and AI research *(R1)*. However, at the same time, the expansion of this digital technology foundation increases the adoption of data-driven self-optimisation *(B2)*. Subsequently, the way people consume is affected by digital technologies and changes: Consumption is shaped by self-tracking and recommendations. These follow the central planner's goal of promoting sustainable behaviours such as personalised diets, energy-saving and subscription models of ownership (first idea for links to basic modules). This 'quantified self-consumption means a reduction in personal freedom as the recommendations are influenced by central planners in the form of nudges. Thus increased power to central planners through loop *(R1)* is countered by a balancing effect *(B2)* from the reduction in personal freedom (creating a S-shape behaviour as seen in figure 8).

With growing adoption of data-driven self-optimisation, the state investment in digital infrastructures increases. This leads to a higher quality of digital infrastructure, which goes along with a higher acceptance of technocracy and at the end more power to central planners *(R2)*. This can be summed up as reinforced power through digital transformation. As this reinforcing loop comes into effect, personal freedom is further reduced: People are putting their trust in data and therefore increase their use of data-driven self-optimisation, which comes at the expense of freedom *(B4)*. This strong decline in freedom goes along with less acceptance of technocracy & utilitarian planning and further reducing power to central planners. Personal freedom is directly linked to the acceptance of technocracy and therefore the power of central planners is affected. Moreover, with less personal freedom, there is less option for citizen involvement in decision making, which would reduce power imbalances in this scenario, and in the end, the power to central planners increases *(R3)*. As central planners are fighting social inequality by reducing the openness of the EU economy and introducing policies for redistribution, the former frustration with libertarian governments decreases (technocracy is an alternative solution approach in this scenario). The lower frustration lowers the acceptance of technocracy and thus the power to central planners.

In this scenario, the power of central planners grows as the digital transformation reinforces their position. Over time, the adoption of data-driven self-optimisation increases resulting in less infringement of environmental limits but at the same time, it comes on the cost of personal freedom (figure 8). The BOT shows that personal freedom, although not part of the initial scenario description, is antipodal to the concentration of power shown in loop *R1*. The challenge of this scenario is maintaining an acceptable concentration of power that does not infringe upon the social dimension but at the same time is acceptable in environmental terms.

3.2. A Pragmatic Path: Transformation within planetary and regulatory limits

The following CLD in figure 9, shows the result from the work process developing CLD for the solution scenario "A Pragmatic Path: Transformation within planetary and regulatory limits".

Figure 9: Scenario CLD: A Pragmatic Path: Transformation within planetary and regulatory limits

The solution scenario *Pragmatic Path* can be summed up as *infringement of environmental limits drives 'strong steering'*. Steering and pragmatic actions are a reaction to shocks linked to the environment and human health. Shocks are a long-term effect caused by the infringement of environmental limits. In short, the scenario CLD and discussions can be summarised as follows:

- Short-termism jeopardises natural capital and reduces future leeway for growth.
- *Infringement of environmental limits* leads to shocks that drive the *regulatory constraints* and *pragmatic actions*.
- Introducing a digital currency has an equivocal effect on *infringement of environmental limits*: it *increases economic growth* (increased

infringement) but also stimulates *pragmatic actions of households* at the end (reduced *infringement on environmental limits*).

- The BOT diagram shows that *infringement of environmental limits* illustrates an oscillating behaviour in concert with strong steering (Figure 10).

Developing the CLD for the scenario *A Pragmatic Path* made additional questions and challenges explicit that could aid the enrichment of the scenario:

- What is the dependence on context scenarios? Guidance of Brussels is important to reinforce regulatory constraints but depending on the context scenario, the future of the global situation outside Europe in 2050 might challenge the power structure of Brussels or even undermine it.
- What could the impact of transparency on financial reporting and sustainability accounting on business activity and infrastructure investment look like in a strong steering situation?
- How can the increased state control over interest rates (via digital currencies) additionally be used to stimulate a sustainable transition?

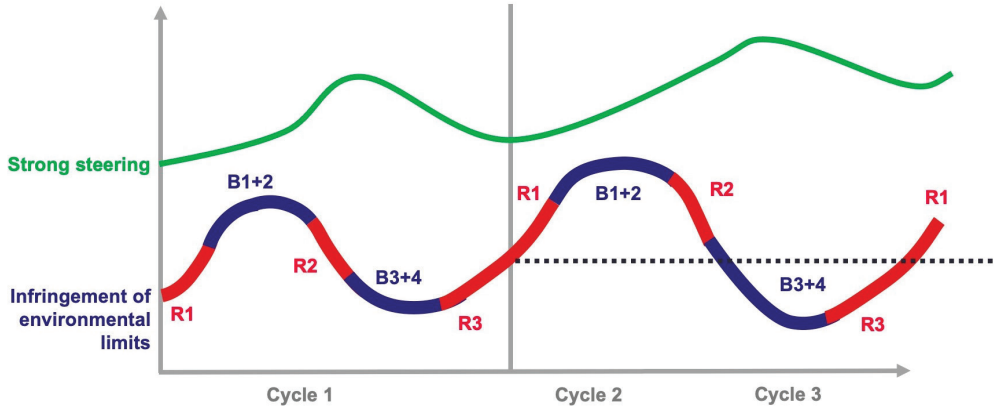

Figure 10: Behaviour over time diagram: A Pragmatic Path

A Pragmatic Path: Telling the story of the scenario CLD

The initial cycle starts with economic growth in the near term that leads to infringement of environmental limits, where it builds up and leads to shocks to the environment and human health *(R1)*. Shocks erode natural capital and in turn expedite the infringement of environmental limits. With shocks present, rigorous regulatory constraints are put into play in order to limit the pressure on environmental limits directly *(B1)*. Moreover, constraints weaken economic growth, which balances the infringement of environmental limits *(B2)*. Regulatory constraints are drawing their power from anticipatory policy design and long-term goal-orientation. Brussels is guiding and steering the regulatory efforts, which in turn reinforce the regulatory constraints *(R2)*. Amid shocks, steering receives more support and power, thereby reinforcing regulatory constraints even more *(B3)*. Based on strong steering, a digital currency is introduced and becomes accepted. Digital currency allows controlling of interest rates and therefore employment. As a consequence redistribute income and wealth is a possibility. The increased financial leeway is used by pragmatic households to live a sustainable lifestyle

given the environmental shocks. The pragmatism of households means sustainable lifestyles and therefore the infringement of environmental limits is reduced *(B4)*. But the digital currency also reinforces the infringement of environmental limits: The digital currency increases the transparency on financial reporting and sustainability accounting which reduces tax evasion and avoidance. This, in turn, increases economic growth and thus the infringing environmental limits are stronger. The end of the second cycle starts a shift towards a lower level of infringement of environmental limits. This CLD does not contain a barrier/limiting factor since these already exist indirectly in the loop description. That said, it does not indicate that these do not exist in the scenario, but rather that it was not necessary in order to communicate the scenario behaviour.

In summary, this scenario is maintained through strong steering that is reinforced through anticipatory policy design (*R2*). This allows for a flexible combination of "agile" planning and regulatory constraints. The key to further develop this scenario would be to explore in-depth what items in anticipatory policy design create a positive driving force and win-win setup towards strong steering and regulatory constraints.

3.3. Ecotopia: Post-growth collaboration

The following CLD in figure 11, shows the result from the work process developing CLD for the solution scenario "Ecotopia: Post-growth collaboration".

Figure 11: Scenario CLD Ecotopia, a post-growth collaboration.

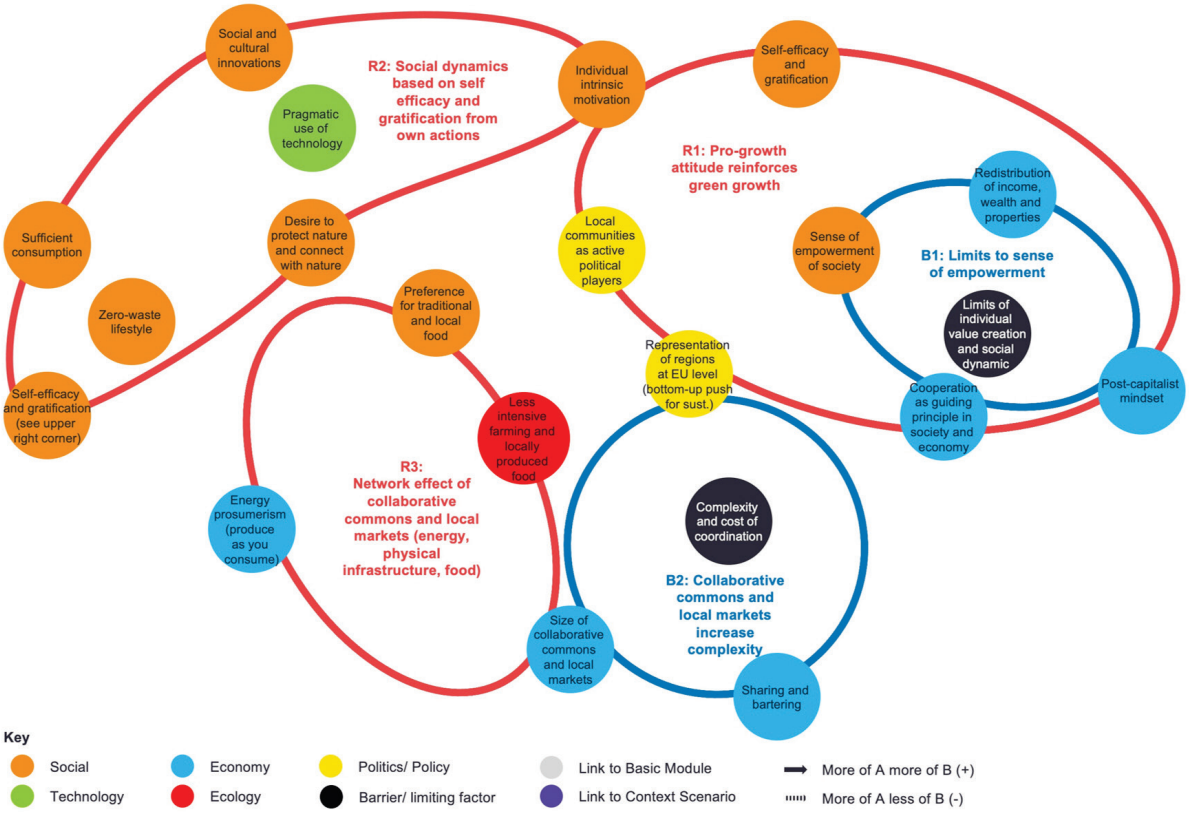

Figure 12: Aggregated loops of the scenario Ecotopia

The solution scenario *Ecotopia: Post-growth collaboration* can be summed up as self-empowerment individual behaviour drives a change regarding the way society, politics and the economy function. The CLD in figure 11 shows that different connections from green market-based incentives and to pro-growth attitude and libertarian ethos merge into the loop behaviour that drives "empowerment". Figure 12 shows the aggregated influence from reinforcing loops (R1, R2, R3) and balancing loops (B1, B2) that impact the "empowerment" in the scenario description. In short, the scenario CLD and discussions can be summarised as follows:

- Self-efficacy and gratification reinforce individual intrinsic motivation and therefore the fundamental shift towards the Ecotopia scenario.
- There is an emergence of the collaborative commons paradigm and local markets based on the desire to protect nature and reconnect with nature and a post-capitalist mindset.
- The main limiting factors that steer the evolution of the scenario is "complexity and costs of coordination" that regulate administration, and "limits of individual value creation and social dynamics" that regulate self-empowerment
- Self-empowerment shows cyclical evolution towards saturation of how much value creation is possible (limits of individual value creation and social dynamics), BOT is shown in Figure 14.

Developing the CLD for the scenario *Ecotopia* generates additional questions and challenges explicit that could aid the enrichment of the scenario. These questions arise from the influence of the sub-system upon Ecotopia (Figure 13). :

- If the complexity and costs of coordination cooccur with a pragmatic attitude to technology: How can technologies or social innovation reduce transaction costs?
- Local land availability could put a limit to the sustainability of the scenario Ecotopia. The competition for local land increases as different production-consumption systems would consume local land (Figure 13). For instance, food and energy, and also the development of "Ecocities" require local land.
- How would the production-consumption system look like given this profound change in society, politics and economy?
- Local demand for materials and resources increases as the size of the collaborative commons increases (Figure 13). How can this demand be sustained? Do circular economy approaches provide a sufficient answer? Are more imports from outside Europe and exchange between Europe required?
- Sufficient consumption could reduce state revenue and economic growth. How can the necessary level of public services and innovation activity be achieved and be sustained?

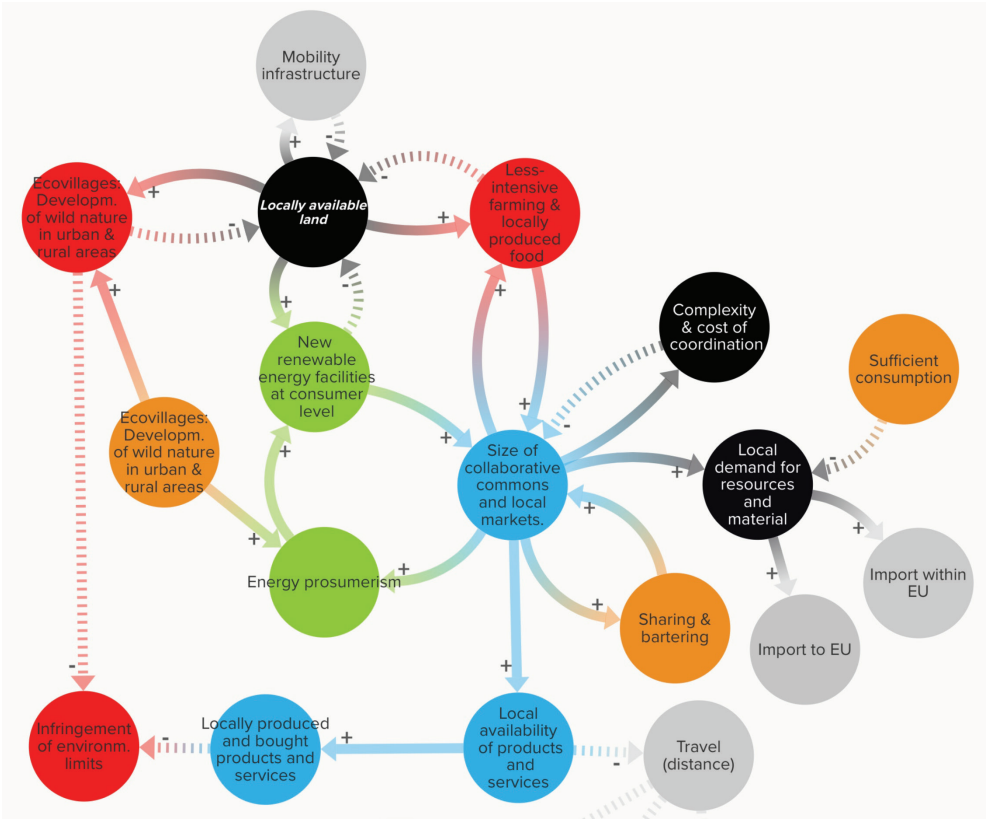

Figure 13: Locally available land and local demand for resources and material (a simplified representation of the CLD to highlight the importance of both items)

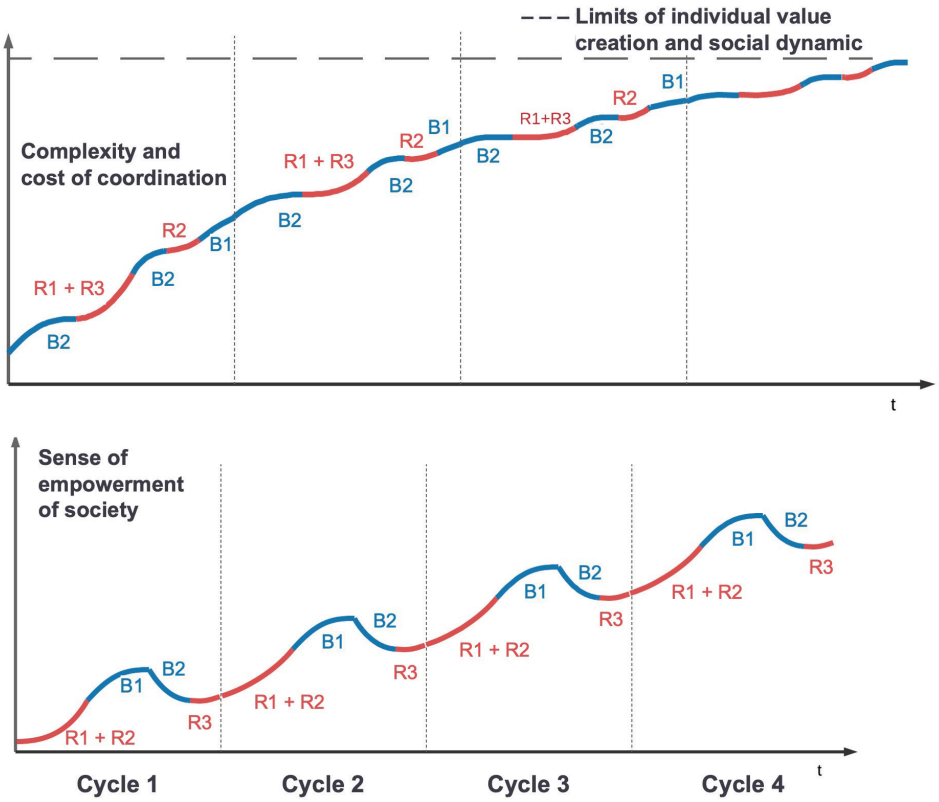

Figure 14: Behaviour over time diagram for Ecotopia. The sense of empowerment of society is limited by the complexity and cost of coordination in administration and limits to individual value creation (and social dynamic), driven with absence of AI technology.

Ecotopia: Telling the story of the scenario CLD

The BOT in figure 14 shows that there are 5 main loops creating the behaviour of the Ecotopia scenario. The scenario has a strong reinforcing behaviour but the main limiting factor is the "Limits of individual value creation and social dynamics" that puts a cap on how much "sense of empowerment of society" is possible for the scenario. This is indicated with the loop B1. The second limiting factor is the "Complexity and cost of coordination", indicated with the loop B2, which links two systems together, i.e. the physical (energy, agriculture, physical infrastructure etc, indicated with the loop R3) system and the social/politic system (loop R1 and R2). Lack of AI technology drives the complexity and cost of coordination indicates how "bottom-up/local communities" management increases in complexity with an increased shift towards a society that is self-sufficient but is an active player in a global context. Pragmatic use of technology (or lack of use) means more mechanisation and increased administrative labour efforts. This is an antithesis to a high technological society that use digitalisation to offload administration tasks from the labour population to AI-management. In short, defining carrying capacity for social conditions, as well as technological conditions would define the limits to growth of the Ecotopia scenario in the current scenario description.

3.4. Green Growth Paradigm: The great decoupling of growth in free markets

The following CLD in figure 15, shows the result from the work process developing CLD for the solution scenario "Green Growth Paradigm: The great decoupling of growth in free markets".

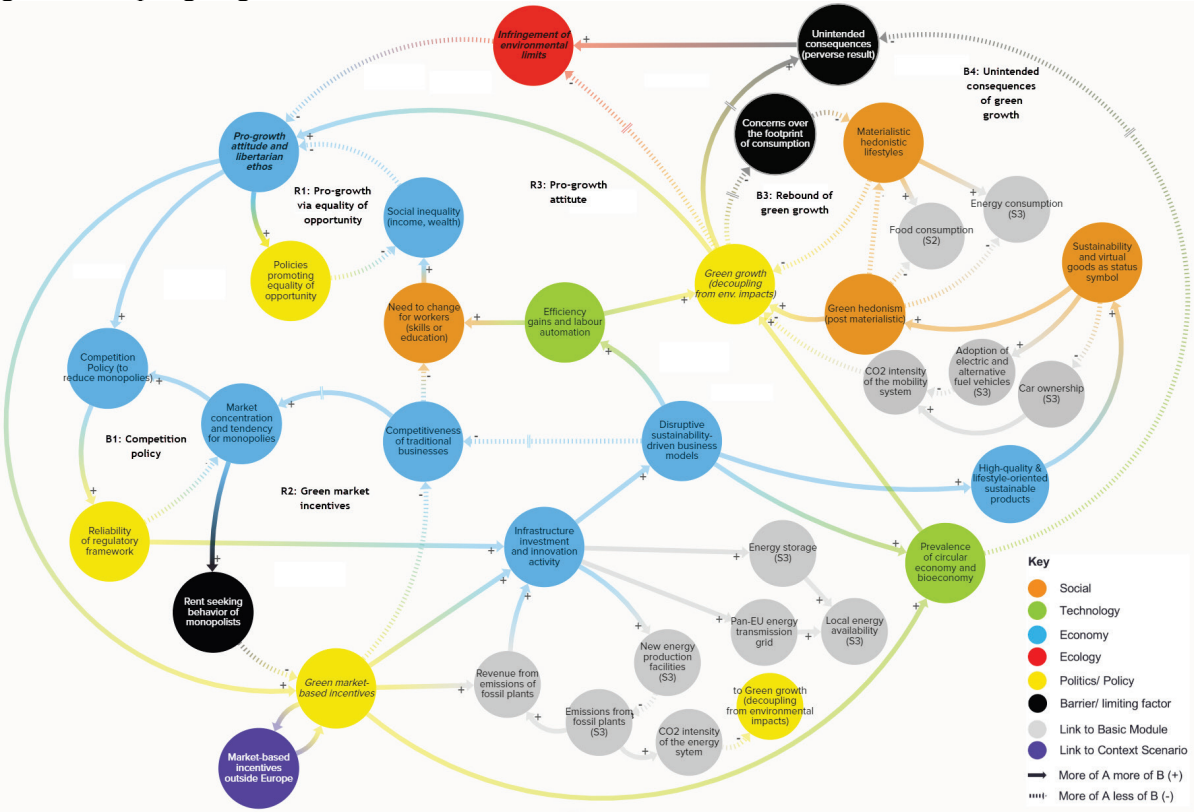

Figure 15: Scenario CLD: Green Growth Paradigm: the great decoupling of growth in free markets.

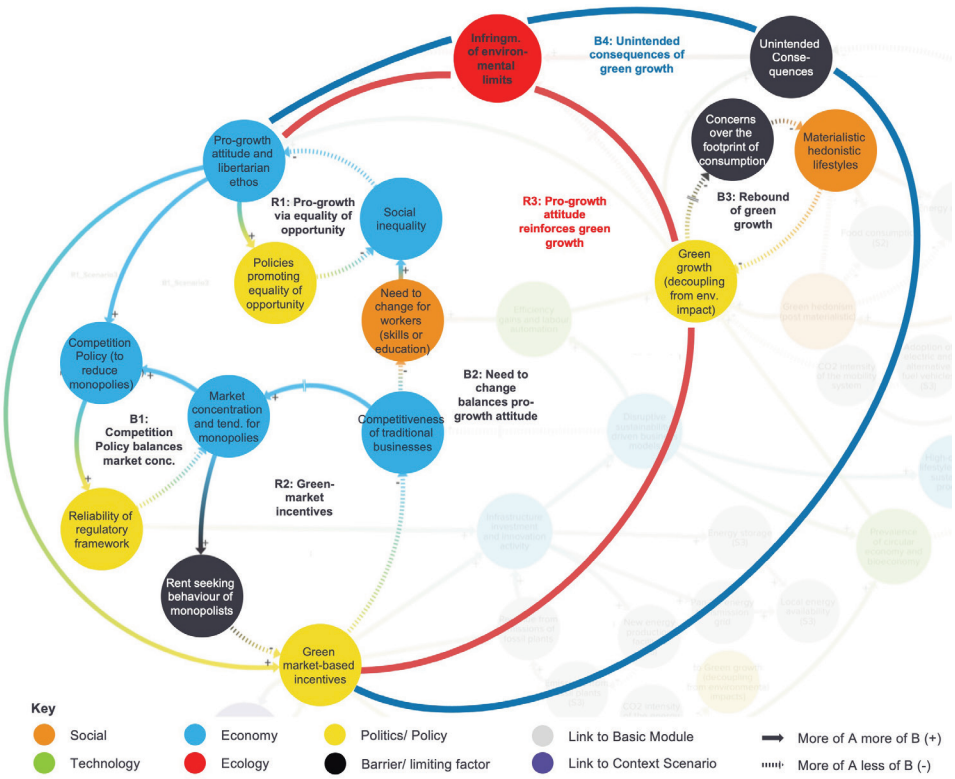

Figure 16: Aggregated loops of the scenario Green Growth Paradigm

The solution scenario *Green Growth Paradigm* can be summed up as the libertarian ethos and belief in the power of free markets to lead green growth. The CLD in figure 16 merges different connections from green market-based incentives and to pro-growth attitude and libertarian ethos into aggregated loops. Figure 16 shows the aggregated loops reinforcing loop 3 (R3, indicated in red) and balancing loop 4 (B4, indicated in blue). In short, the scenario CLD and discussions can be summarised as follows:

- A pro-growth attitude and libertarian ethos pay off in terms of environmental sustainability.
- Green market-based incentives are an important driving force of the underlying subsystems, i.e., figure 15 and figure 16.
- The growing need to change for workers balances support the free market paradigm. Policies promoting equality of opportunity break this balancing loop and reinforce support.
- Pro-growth attitude and green growth increase over time (Figure 17).
- Three Loops (R2, B3 and B4), show barrier/limiting factors that impact the scenario evolution. For R2, the “rent-seeking behaviour of monopolists” hampers the green market-based initiatives. Furthermore, through the green market base initiatives, the green growth is limited by “concerns over the footprint of consumption” as well as unintended consequences impact upon the infringement of environmental limits.

Developing the CLD for the scenario *green growth paradigm* makes additional questions and challenges explicit that could aid the enrichment of the scenario:

- What would be the necessary conditions outside Europe for market-based incentives to work?
- When is this solution feasible?
- How to ensure a level playing field for EU industry?
- What are potential mitigation possibilities for unintended consequences that could jeopardise green growth? Given that this is a solution scenario, there would be some solutions introduced. What could be levers to reduce or reverse unintended consequences?

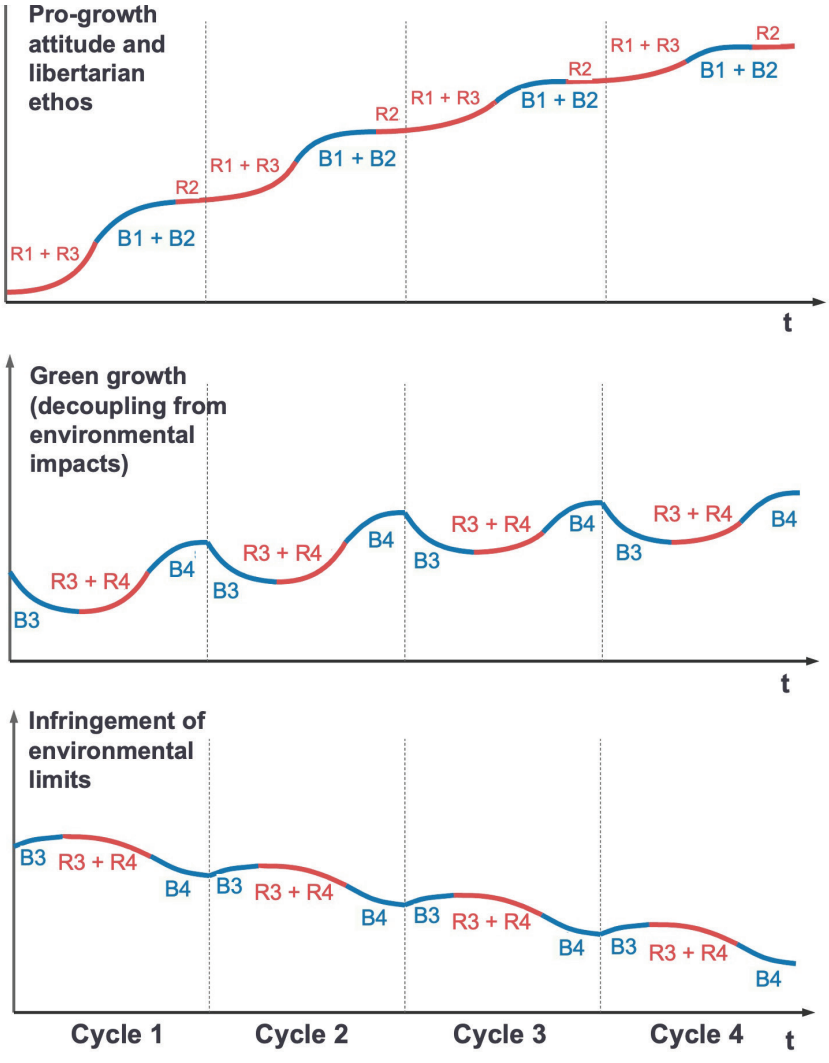

Figure 17: Behaviour over time diagram: Green Growth Paradigm

Green Growth Paradigm: Telling the story of the scenario CLD

The Green growth scenario can be analysed as two "loop behaviours" that are interacting to create the overall scenario behavioural development. In "loop

behaviour 1" describes the evolution of the "Pro-growth attitude and libertarian ethos" as the philosophy behind the economic green growth. We can see that 4 loops are interacting dynamically, the economic system and the policy/regulation part (indicated with loops R1, R2, B1, B2), which is the core driving force that influences all the other factors in the CLD. Green Growth is a result factor (or the gauging parameter) that indicates a "decoupling" is taking place. The "loop behaviour 2" takes into account the unintentional consequences of "decoupling", as an impact upon social factors (loop B3) and through "bioeconomy" upon the factor "unintended consequences". For instance, the green growth, i.e. decoupling of economic growth and consumption, could create a rebound effect: concerns over the own footprint of consumption could decrease and give rise to more materialistic hedonistic lifestyles. Combining this "loop behaviour of loop 2" creates an overall scenario behaviour that is saturating (balancing goal-seeking system). This saturation effect (limits to growth) is initiated by the factor "Rent-seeking behaviour of monopolies" that is a result of market concentration and tendencies for the formation of monopolies. The long-term limiting factor is the "infringement upon environmental limits", where "zero" environmental impact is impossible. Economic activity will always have an impact and Green Growth will inherently reach its limits of maximum efficiency.

In summary, the added barrier/limiting factors added in this scenario serve to show limits to economic growth (*R2*). The further development of this scenario would benefit in identifying further driving forces that are coupled to loop *B1* and *R2* and especially the dynamic of concentration of monopolies in the green market that can in the long-run have a contrary effect upon green growth.

4. Conclusions

4.1. Concluding remarks

The purpose of this project was to explore and showcase how CLDs can be used in the context of the *Scenario Method*. The project shows that applying CLDs in the context of the *Scenario Method* provides an added value with respect to two dimensions, the processes level and the content level. On a process level, CLDs constitute one additional lever to critically reflect and visualize complex interdependencies that are conveyed in the written text of scenario narratives. In that sense, CLDs complement the presentation of scenarios from a different angle. On a content level, it became clear that this rather novel approach of combining CLDs and scenario narratives is helpful not only to critically reflect scenario narratives but enrich them by thinking through balancing and reinforcing loops. This mode of creative thinking helps to uncover new implications, conflicts between different actors or solutions for issues as well as additional aspects that help to make a scenario more plausible. In addition, the project shows that different scenario CLDs can be compared and potential transitions between scenario could be discussed in a further step.

The results presented are a metanalysis of the interpretation of the scenarios developed in the project SSE 2050. The results indicate that the solution scenarios produced from the SSE 2050 vary slightly in how the framing of system boundaries and the point of departure in the narratives is treated. Furthermore, the CLD can either be generic or specific in describing the scenario. For instance, Ecotopia has a specific focus on the induvial level and the scenario CLD description serves to fulfil the individual needs on a personal level. The CLD factors are abstract and value-laden to illustrate the social values and their dynamic behaviour, showing a clear distinction between the personal level and the generic level. The solution scenarios for A pragmatic Path, Green Growth Paradigm and Utilitarian Technocracy for Good, show factors that are more generic in the CLD descriptions (e.g., society being affected vs the individual level etc).

All the solution scenarios required support factors to show barriers/limitations to have the CLDs work in terms of appropriate reinforcing and balancing behaviour. The solution scenarios tended to highlight reinforcing behaviour in the narratives and omit the description of limiting factors, therefore showing unlimited growth. This illustrates the difference between the Scenario Method and the CLD approach. The narratives produced from the Scenario Method describe a situation picture of the desired state without going into details about how the scenarios work internally, whereas the CLD approach investigates how the makeup of the scenario is constructed through feedbacks. From the system dynamic approach, reinforcing loops are temporary and limiting factors will ultimately constrain growth in all systems. Therefore, during the analysis, it was necessary to identify and insert specific barriers/limitations to create balancing feedback loop behaviour within the

solution scenarios. Apart from the scenario, A Pragmatic Growth, all the scenarios required adjustment to illustrate feedback constrains, and the scenario Ecotopia required the most adjustment.

One of the conclusions from the study points toward the necessity to be explicit in the description of the solution scenarios (and its supporting projection description) since the factors derived for the CLDs need explicit language. This will aid in enriching and identifying key factors of influence in the scenarios, and furthermore validating and preparing the results for further communication is the next step. The study shows that scenario CLDs can be a point of departure to enrich the scenarios further and complement a foresight process (here: scenario analysis).

This study points towards five different use cases of the CLDs that warrant further consideration for follow-up activities in the context of SSE 2050 and beyond[5]:

1. Giving an understanding of the solution scenario narratives by framing them in space and time and creating dynamic storytelling.
2. Identifying challenges and shortfalls in the solution scenario narratives that need to be addressed in order to enhance robustness and reliability.
3. Stimulating the discussion on how external systems influence the scenario narratives, i.e. production and consumption systems (energy, food, mobility).
4. Connecting solution scenarios and context scenarios: Reconciling the goals and actions of Europe and the goals and actions of other actors outside Europe.
5. Identify and integrating additional sustainability indicators into scenarios through the CLD building process.

[5] The order of follow-up activities shown does not imply any prioritisation or recommendation.

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6. ANNEX

6.1. Solution Scenarios - Sustainable Europe 2050

Annex 6.1. presents the Solution Scenarios – Sustainable Europe 2050, scenario narratives that were used as a starting point to develop the scenario CLDs present in chapter 3 (EEA/EIONET NRC FLIS, 2020). It is to be noted, that the scenario narratives have not been adapted based on the outcomes of this CLD project. There might be marginal differences compared between the scenario narratives and the CLDs presented in this report here.

Scenario 1: Utilitarian Technocracy for Good – Society is steered towards Sustainability

Scenario Narrative
By 2050, there is widespread acceptance that prosperity and sustainability is best achieved through central planning. Utilitarian governments rely on engineering the digital sphere and on the market power of their state-driven big businesses to steer behaviours towards desirable outcomes. Critical voices that regard central planning and digital tools as authoritarian and illiberal practices died away. In fact, people acknowledge their own limitations, and digital tools, do hit the zeitgeist of quantified-self and self-optimisation. A strong digital infrastructure is the backbone of social change. People are steered towards a mix of buying efficient, sustainable products and the sustainable use of products. Political capitalism and technocracy led the way to achieve the vision of a Sustainable Europe.

Main Drivers of the Scenario
- Frustrations with liberal market economies produce a swing towards rather utilitarian governance
- Society is highly rational, puts trust in experts and data, and seeks to avoid uncertainty and improve well-being

Scenario Highlights
- Dominant state bureaucracies shape societal outcomes towards sustainability: grounded in widespread acceptance that prosperity and sustainability is best achieved through social and economic planning
- Utilitarian: emphasis on gatekeeping of information and discourse, steering attitudes and behaviours towards socially desirable outcomes
- Large investment in IT enabled governance and monitoring and analysis of environmental pressures and trends to allow for efficient use of biotic resources
- Quantified-self services and nudges are accepted as tools to overcome own limitations, weaknesses or foster pro-social and pro-environmental lifestyles

- Digital transformation of all aspects of life, economy and the built environment (e.g. ubiquitous connectivity, AI systems, high automation in industry and agriculture)
- Strong state control of businesses and increased state ownership in some areas lead to "big businesses" (e.g. business that collect vast amounts of behavioral data from users and develop powerful AI tools)
- National governments are strong and independent but actively coordinate to promote, e.g. economic exchange and environmental management (e.g. regarding global import and export of energy and the role of big energy companies in the EU).
- The public is informed about policies, current issues and decisions. It is widely accepted that many policies are adopted without the participation of citizens. But there are optional digital forms of societal involvement that function as a corrective (e.g. clicktivism). NGOs work hand in hand with governments.

Scenario 2: A Pragmatic Path – Transformation within Planetary and Regulatory Limits

Scenario Narrative

By 2050, the necessary transformation towards a strong sustainable Europe is managed by a powerful and steering Brussels. Growth is promoted but only within environmental limits: Pragmatic and strict regulations shape what is available on the market and innovation takes place within the regulatory borders to ensure the protection of natural capital. Lessons were learned from recurrent shocks linked to environment and health and these shocks served and serve as a form of the extrinsic motivation to live sustainable lifestyles. All this fosters an anthropocentric transformation with a focus on sufficiency and consistency and led the way to achieve the vision of a Sustainable Europe.

Main Drivers of the Scenario

- Recurrent shocks linked to the environment and human health have brought a major shift in the economy, politics and public awareness which led to pertinent and pragmatic sustainability-orientated solutions and actions
- The majority of robust (international) environmental rules and the actions to promote the necessary transformation comes from a strong and steering Brussels, in which sustainability is a strong guiding principle

Scenario Highlights

- Far-reaching political and economic integration at European scale with a strong emphasis on centralised structures and state and interstate responsibility: Support of shared environ-mental commitments, fiscal transfers between regions, privately-owned platforms, etc.
- Agnostic on economic growth: economic activity and liberal markets are promoted but only within environmental limits and rigorous regulatory constraints

- Strongly supporting a reflexive and adaptive approach to system innovation with long term goal orientation, e.g. implementation of a central bank digital currency
- The majority of people is convinced that there is no choice but to adopt sustainable lifestyles and attitudes with respect to ecological sustainability in order to secure their very own well-being in the long term
- Energy production is tailored to geographical regions in Europe with semi autonomic characteristics regarding self-sufficiency; Regions in the north rely heavily on hydro-electric/biomass whereas southern regions rely solar/wind focused
- Anticipatory policy design, meaning a strong emphasis on precaution, acknowledging uncertainty in managing complex systems and innovation

Scenario 3: Ecotopia – Post-growth Collaboration

Scenario Narrative:
By 2050, society and economy have undergone a profound socio-economic transformation. Daily life, production and consumption as well as the political framework are shaped by active local communities. Sufficient lifestyles that are lived by conviction gave rise to social and cultural innovation. Innovation goes clearly beyond new technologies. Communitarianism not only encompasses the community but also nature itself: Living within the boundaries of nature is perceived as the highest good and nature is actively improved and protected. A strong de-growth orientation as well as the wish to reconnect with nature constitute the dominant mindset that led the way to achieve the vision of a Sustainable Europe.

Main Drivers of the Scenario
- The need to preserve and reconnect to nature and the local community is part of society's common sense and has a huge impact on daily life, politics and the economy
- Pragmatic and subordinate use of technology following the concept of "less is more" and supporting self-sufficiency, low carbon and low resource-intensive lifestyles

Scenario Highlights
- Fundamental shift towards a post-capitalist paradigm including a degrowth orientation, which actively is promoting the demarketisation of society
- Largely mutual / cooperative ownership of large companies and a strong preference for services and sharing over private ownership
- Communitarian and egalitarian system with a focus on bottom-up processes and representation of local regions at European scale (following the approach "Think globally, act locally")

- Direct engagement of citizens and further non-governmental forces in decision-making and experimentation in governance: Lessons learned are shared and discussed broadly and active participation is key to success
- Decentralisation and subsidiarity play an important role: Energy production is highly decentralised and put into the hands of the consumer on micro-level and decentralised digital currencies are used to boost the local economy or reward unpaid work (e.g. care for the elderly)
- Regionally produced food and regenerative agriculture, wild urban nature areas and parks that are connected with reserves or corridors in nearby rural areas as well as evermore emerging ecovillages, to just name a few, are the results of the reconnection process to nature and the local environment and the leading paradigm to live in harmony with nature

Scenario 4: Green Growth Paradigm – The Great Decoupling of Growth in Free Markets

Scenario Narrative

By 2050, a philosophy of pro-growth, liberal and free markets reigns. Market-based incentives aim to protect essential natural capital and provide a framework for innovation activity, infrastructure investment and education. This gives rise to a transformation that centres around efficiency and consistency. Growth has lost its fright thanks to technological advances and profit-oriented circular economy markets that allow decoupling growth and private consumption from environmental impacts. Society's own free will, responsibility and motivation together with market-based instruments led the way to achieve the vision of a Sustainable Europe.

Main Drivers of the Scenario

- Pro-growth attitude that is grounded in an understanding that economic growth is necessary to sustain and enhance societal well-being
- Paradigm of free markets and decoupling economic growth from environmental impacts through technology advances

Scenario Highlights

- Efficiency gains play a key role. There is a strong belief that environmental impacts and other externalities can be offset by investments in technologies, skills and infrastructures (e.g. pan-EU renewable energy system and new techniques for large scale agriculture).
- Thanks to the strong decoupling, economic growth, hedonistic lifestyles and sustainability are compatible. They are not mutually exclusive and go hand in hand by 2050
- Market-based instruments create an incentive for companies to correct environmental and social harms

- Policy design pursuits the idea of a reliable regulatory framework instead of a more adaptive approach in order to facilitate security of investment and business activity
- Free markets, even libertarian ethos promotes the emergence of disruptive business models and a lively circular economy
- The bioeconomy is highly integrated into the economy through various profitable biomass value chains
- EU policy design is based strongly on subsidiary principles, cooperation between EU countries is flexible and pragmatic
- Following the liberal ethos, policy focusses on equality of opportunity, rather than equality of outcomes (e.g. strong investments in education and (re)training); inequality is accepted given that social mobility is high

6.2. Basic Modules

The basic modules presented here are taken from a previous study of Lorenz and Haraldsson (2014). This project did not aim to develop entire new bas modules. The basic modules are assumed to represent a sufficient level of detail of the basic behaviour of the production-consumption systems food, mobility and energy. The project goal was to see how scenario CLDs can be connected to production-consumption systems. Complex analysis was out of the scope of this project. Therefore, only some of the possible connections between scenario CLDs and basic modules are shown in the following figures. The discussions during virtual meetings show that connecting basic modules and scenario CLDs can help to enrich the scenarios and gain a better understanding of how production-consumption systems work in the different scenarios. Some of those discussion points can be found in Chapter 2.

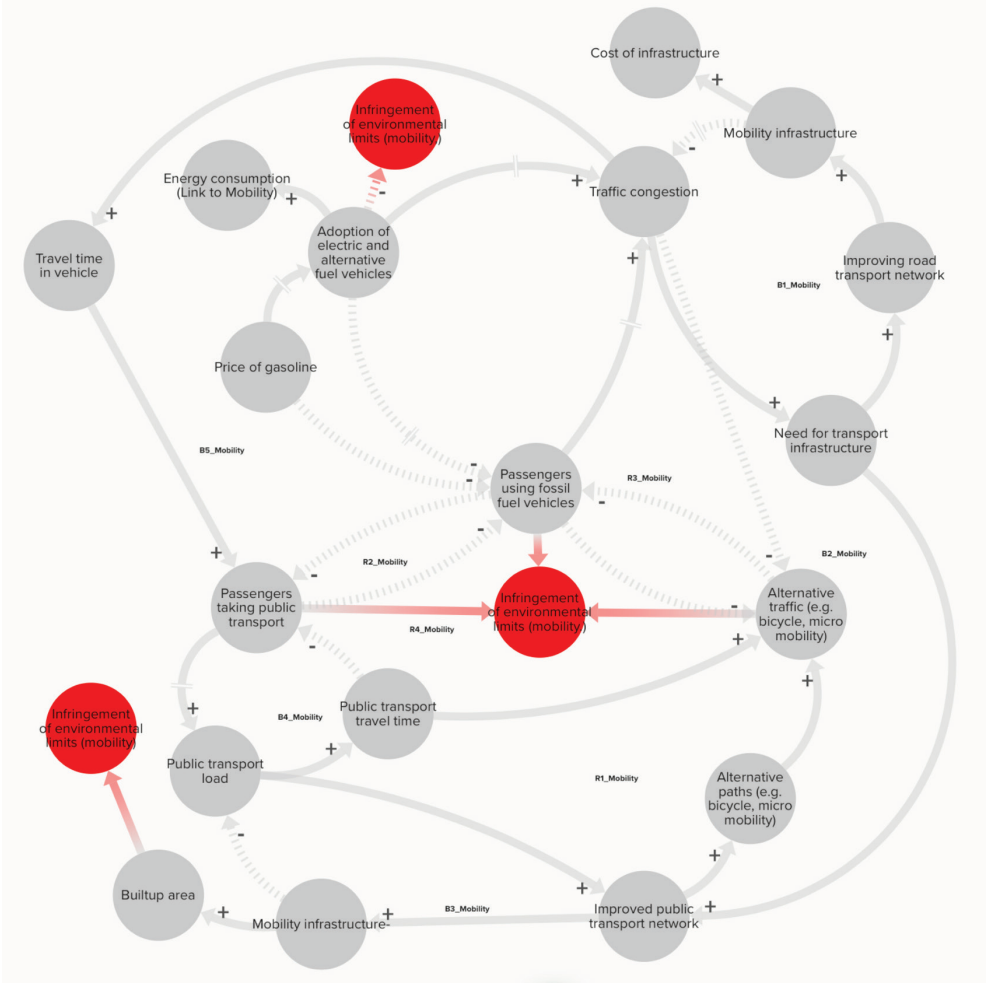

Figure 18: Basic module mobility (based on Lorenz and Haraldsson 2014)

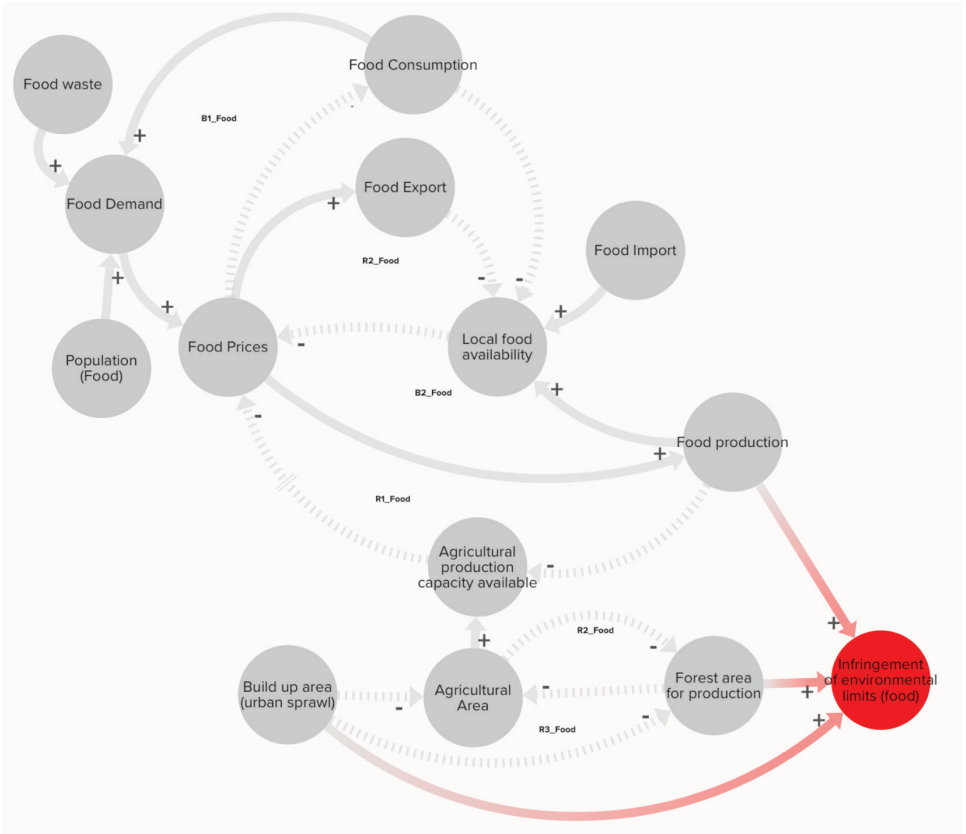

Figure 19: Basic module food (based on Lorenz and Haraldsson 2014)

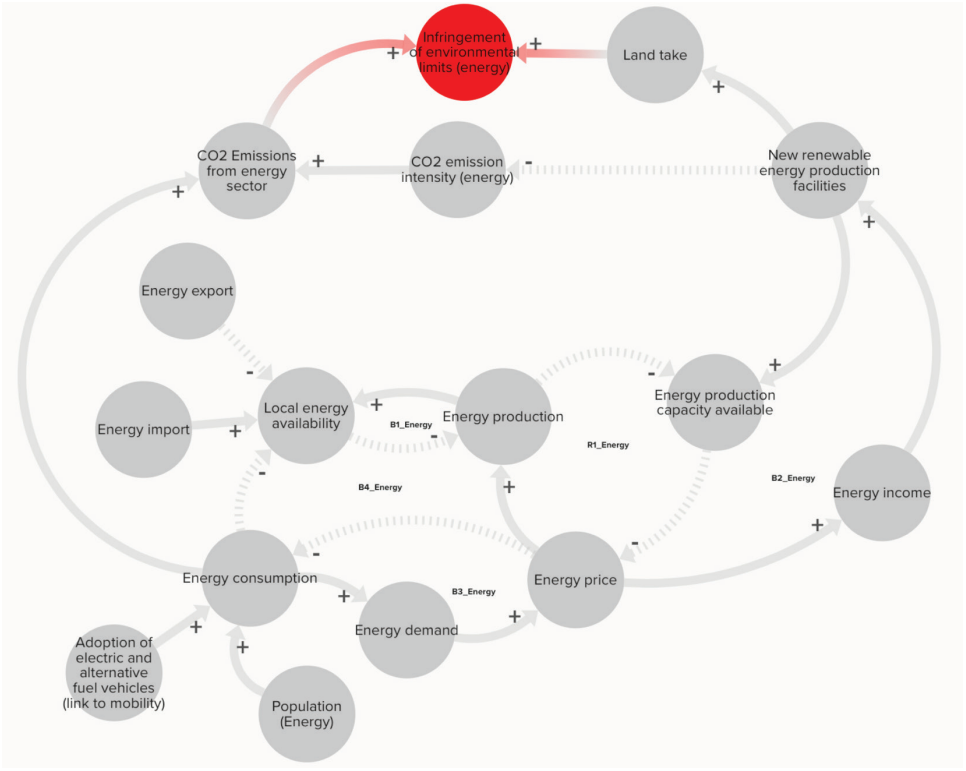

Figure 20: Basic module energy (based on Lorenz and Haraldsson 2014)

6.3. Potential next steps and follow-up

The remainder of this section describes each potential follow-up activity briefly. One example identified during this pilot exercise is presented per potential activity. A screenshot that might be used for presentations illustrates each example. The points of discussions and key insights can be found in Chapter 2.

1. Added value for presenting scenarios and understanding scenarios in a dynamic way: Scenario CLDs and the BOT diagrams can be used to aid presentation and understanding of the SSE 2050 solution scenarios (Figure 18). The project showcased how the scenario narratives and corresponding key factor projections can be used to develop CLDs.[6]

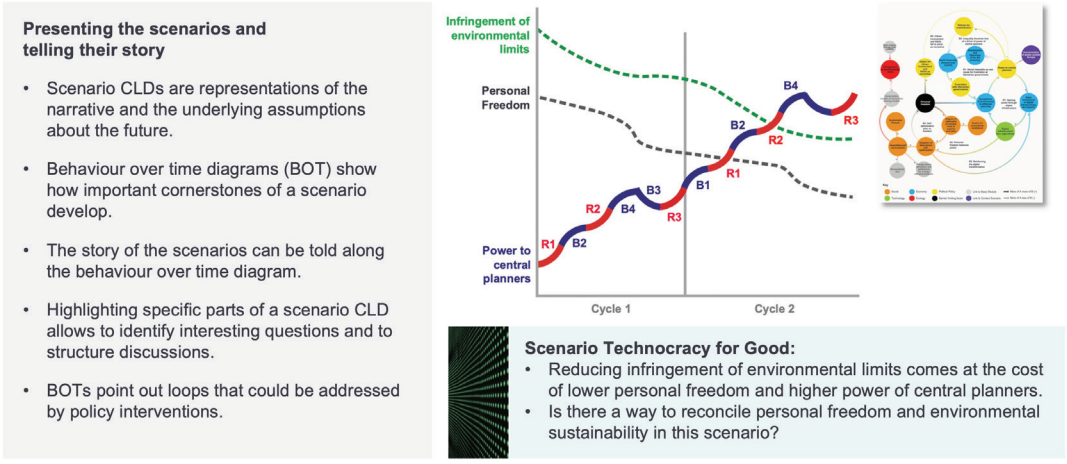

Figure 21: Presenting the scenarios and telling their story with the help of CLDs

2. Developing CLDs creates awareness of the challenges, barriers to change and limiting factors of the different solution scenarios (Figure 19). The solution scenarios developed are intended to be enriched in 2021 and beyond. A better understanding of challenges, barriers to change and limiting factors allows identifying of potential policy levers. This discussion may also be informed by the BOT diagrams.

[6] In the scenario method, key factors can be defined as follows: Key factors have a great impact on the focal topics (here: Sustainable Europe in 2050) and have a high degree of uncertainty. Due to the high degree of uncertainty, different possible projections are possible. Projections describe different states of a key factor can in 2050.

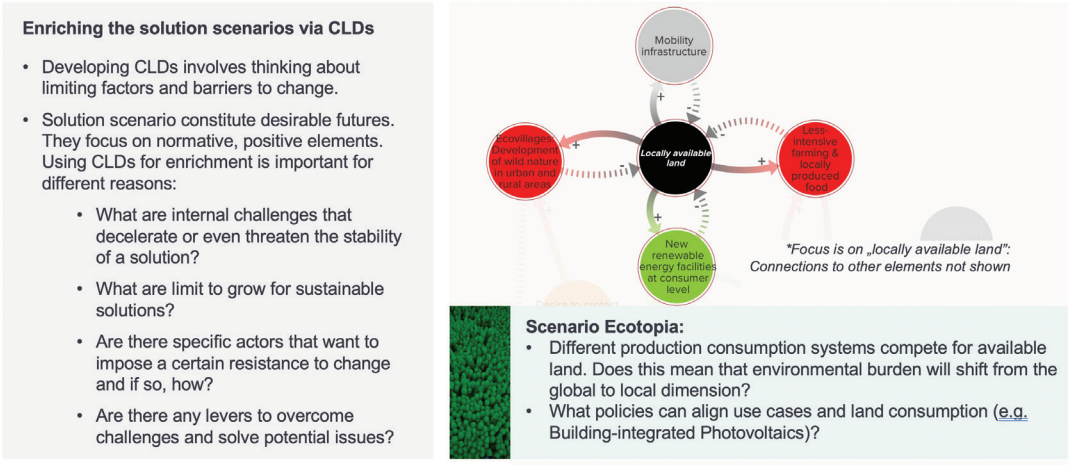

Figure 22: Thinking about limits to the solution scenarios creates awareness for challenges that need to be overcome or could jeopardise an aspect of a solution

3. The project here intended to show that it is possible to link production-consumption systems to scenario CLDs. Using the scenario CLDs could help to think about how production-consumption systems (mobility, energy and food) could look like in each of the solution scenarios (Figure 20).

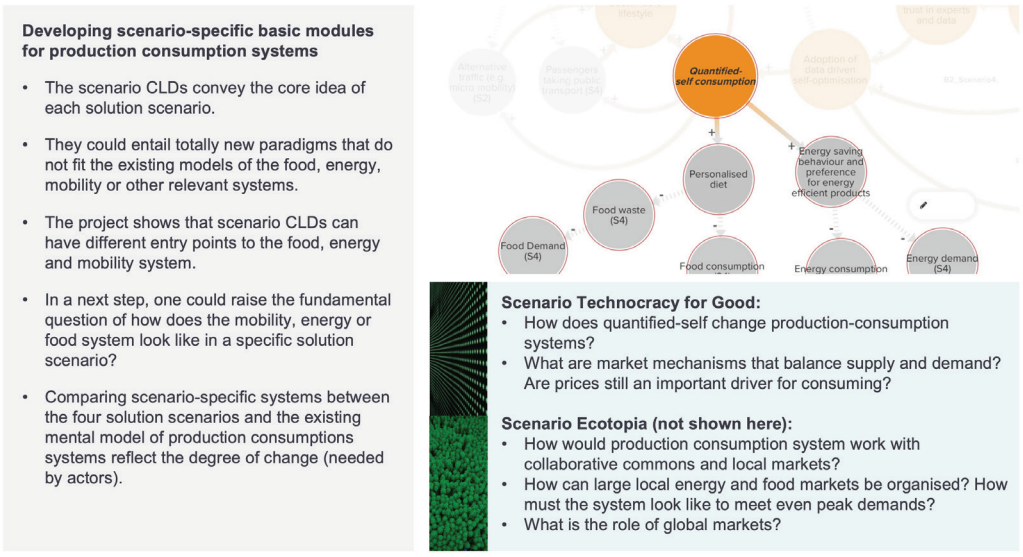

Figure 23: Stimulating the discussion on how production consumption systems could look like

4. The actions of European actors are embedded in a wider context (Figure 21). Two different types of scenarios were developed during the project SSE 2050: Solution scenarios describe possible futures of a sustainable Europe. Also, the SSE 2050 context scenarios describe possible futures outside Europe. The understanding of the interplay between those scenarios can be informed by using CLDs.

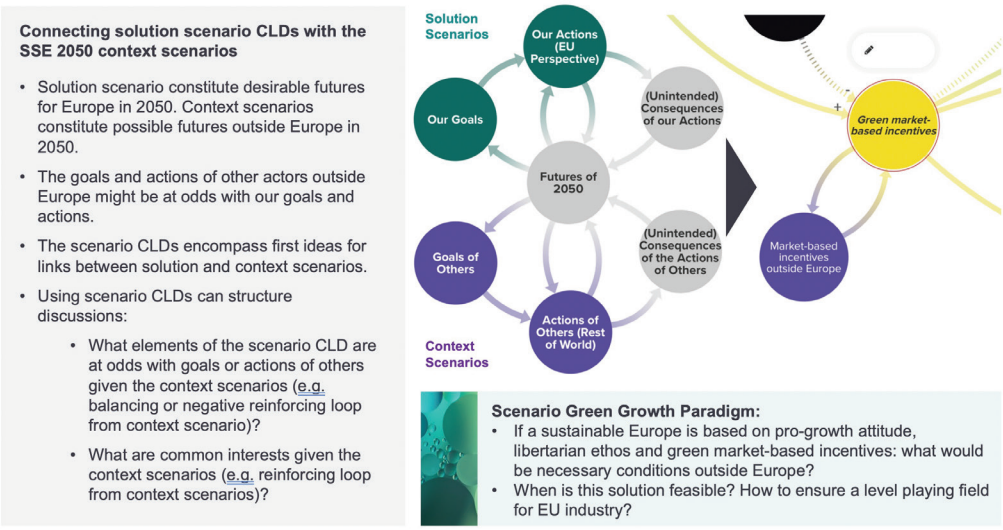

Figure 24: Connecting solution scenarios and context scenarios

5. If it is given that Europe in 2050 is sustainable, then one can identify elements that define its sustainability (Figure 22). The project shows that those elements of sustainability like an infringement of environmental limits can be connected to the scenario CLDs. This is relevant in the context of monitoring the EAP8 and European Green Deal because both constitute potential sources for elements of sustainability. A follow-up project could gauge the success of selected elements in the different scenarios. The behaviour over time of additional elements could be analysed and ideas for policy interventions might be derived on this basis.

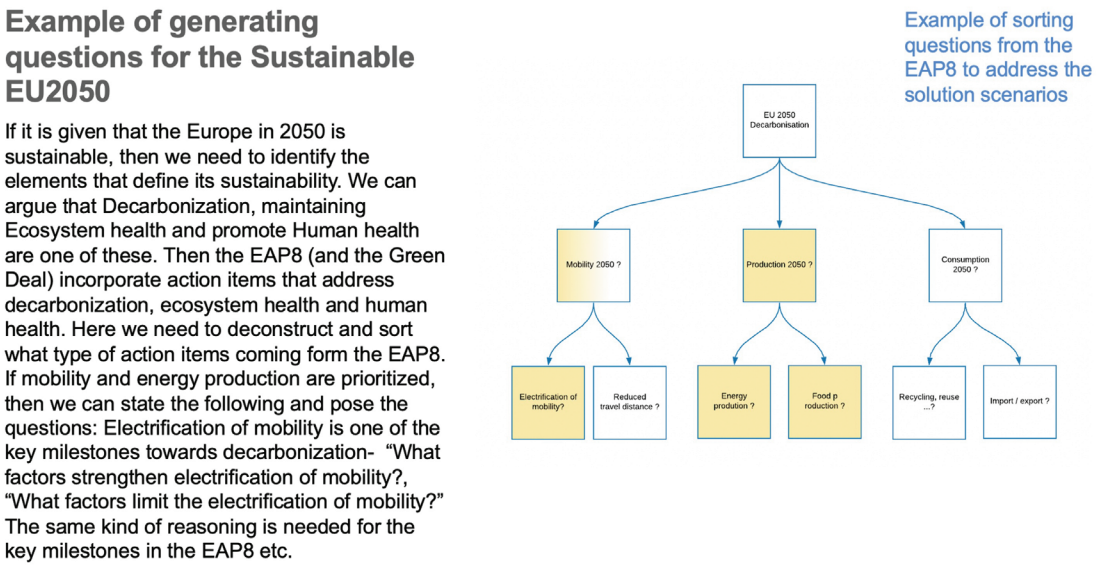

Figure 25: Integrating additional sustainability indicators into scenario CLDs

In addition to the aforementioned follow-up activities related to qualitative modelling, translating the scenario CLDs or parts of them into simplified numerical

models could be another option. For instance, the scenario CLDs can be rebuilt in iMODELER for further Qualitative Indexing Analysis (QIA) Figure 23. The qualitative indexing analysis has been demonstrated to show loop behaviour and BOT for selected factors (Haraldsson and Wiktorsson, 2014; Haraldsson, 2020; Haraldsson and Ólafsdóttir, 2018). In figure 23, the first trial run for QIA on the Solution scenario Green Growth Paradigm is shown.

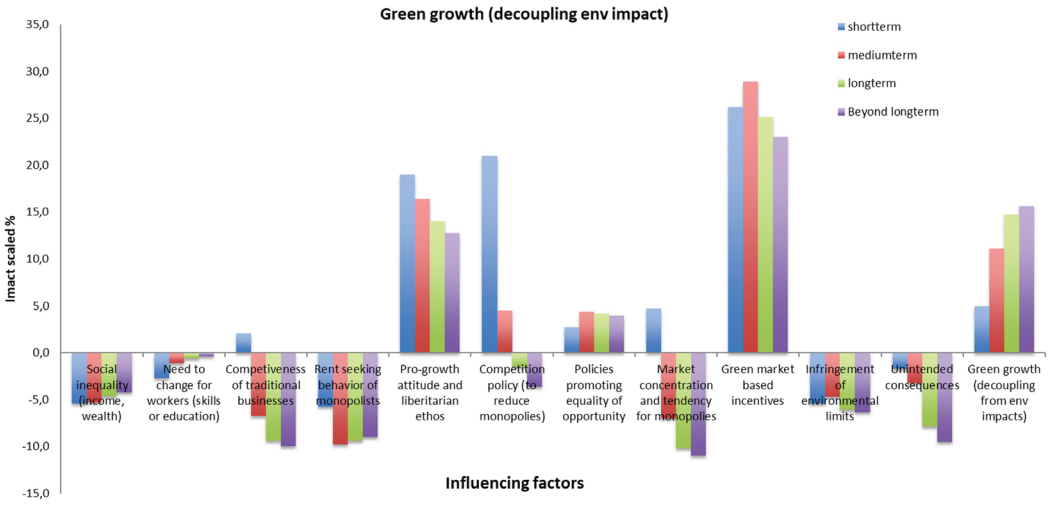

Figure 26: Analysing the scenario CLDs with qualitative indexing analysis. Example of solution scenario - Green Growth Paradigm: The great decoupling of growth in free markets.

Using systems approach to integrate Causal Loop Diagrams modelling in the foresight project Scenarios for a Sustainable Europe 2050

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The main purpose of this study was to showcase the use of Causal Loop Diagrams (CLD) analysis of the scenarios developed in the EIONET NRC FLIS project Scenarios for a Sustainable Europe in 2050 (SSE 2050). This study attempts to abridging the foresight Scenario Method with the system dynamic qualitative approach using the Causal Loop Diagramming method. In the study, the four narratives (Ecotopia, A Pragmatic Path, Green Growth Paradigm, Utilitarian Technocracy for Good) from the SSE 2050 project were interpreted and contextualized to develop the CLDs. Combining the results of the Scenario Method from SSE 2050 with systems dynamics modelling was a special feature of this project.

The overall goal of the project was to 1) Show how scenario narratives can be illustrated using feedback loops and driving forces to show the evolution of different key factors over time. 2) Analyze and enhance the plausibility of each scenario as a function of time and improve the scenario consistency by enriching the scenarios. 3) Show how systemic change can be facilitated in the normative scenarios being studied.

The results indicate that the solution scenarios produced from the SSE 2050 vary slightly in how the framing of system boundaries and the point of departure in the narratives are treated. Furthermore, the CLD can either be generic or specific in describing the scenario. All the solution scenarios required support factors to show barriers/limitations to have the CLDs work in terms of appropriate reinforcing and balancing behaviour. The solution scenarios tended to highlight reinforcing behaviour in the narratives and omit the description of limiting factors, therefore showing unlimited growth. This illustrates the difference between the Scenario Method and the CLD approach.

One of the conclusions from the study points toward the necessity to be explicit in the description of the solution scenarios (and its supporting projection description) since the factors derived for the CLDs need explicit language. This will aid in enriching and identifying key factors of influence in the scenarios, and furthermore validating and preparing the results for further communication is the next step. The study shows that scenario CLDs can be a point of departure to enrich the scenarios further and complement a foresight process.

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