Deliverable D5.5

Raw Materials Foresight Guide

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Notice

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PURPOSE

The purpose of Deliverable 5.5 *Raw Materials Foresight Guide* is to provide guidelines to conduct Foresight exercises and methodological recommendations for the mineral raw materials policy making, under the context of strategic raw materials intelligence. It seeks to increase efficiency and effectiveness of the EU activities related to raw materials policy planning.

EXECUTIVE SUMMARY

Through an ontology-based online platform, the European Raw Material Intelligence Capacity Platform (EU-RMICP), the MICA project aims at supporting raw materials stakeholders in translating relevant data, information, methods and tools into appropriate knowledge and intelligence for answering their needs. A number of these different potential questions and needs might frequently encompass forward-looking properties and should therefore appraise the utilisation of forward-looking approaches such as foresight. In that sense, it is important to provide basic definitions, set out relevant references and benchmarks and explain methodological approaches to increase the user capacity to benefit from foresight approaches.

The present report succeeds the work done in reviewing past raw materials foresight case studies (D5.3 *Report on Foresight Logframe*) and the foresight methodology workshop (D5.4 *Report on Pilot Foresight*). The previous work provided the basis for the development of the *Raw Materials Foresight Guide* and its findings.

This report seeks to outline the landscape of potential foresight approaches, methods and tools that can be used to help raw materials stakeholders answer forward-looking questions.

The main findings of this report can be summed up as follows:

- Foresight guidelines are not rigid. They are context-dependant and need to consider many relevant factors such as time horizon, access to resources and objectives to properly suggest roads for foresight implementation. As any other area, foresight can be subject to evolution itself;
- MICA platform queries that have a forward-looking component need to be translated in terms of foresight to better understand how foresight could support in answering such questions;
- Raw materials foresight studies and objectives can relate to multiple areas. Explicit attempts to identify the landscape in which the potential study is located can be informative in supporting the definition of suitable foresight approaches. Such areas are presented with respective foresight implications in a suggested raw materials foresight framework. This report divides raw materials foresight thematic areas into:
    - Geographic orientation: exploration of how to derive long-term socio-economic benefit on a e.g. national level;
    - Policy-supporting: as policies are naturally developed today with a view to the long-term future, the mineral policy context happens in a landscape where it is critical to identify and understand the implications of raw materials future challenges.

  - Sustainability-related: growing concern with the socio-environmental impacts in the raw materials sector coupled with the emergence of sustainability paradigms (e.g. circular economy and resource efficiency) can set the landscape for a variety of raw materials foresight studies;
  - Research & Technology: it is of strategic importance to understand when and where technological breaks can happen, as the dynamics of the raw materials sector can be strongly influenced by such discontinuities. Research and Innovation (R&I) can help tackling identified future challenges and foresight studies can help to frame future paths ensuring the overcome of such related challenges;
  - Supply/demand challenges: the market and economic dynamic of the raw materials sector is of interest to both private and public sector. Understanding associated challenges and possible future consequences is of utmost importance for adopting strategies and viable options, developing policies among other.
- As policy-making needs increasingly more adaptive forms of foresight, setting of monitoring capacities in the EU such as Early Warning Systems can be of great value when dealing with issues such as, but not limited to, ‘supply risk’ in the raw materials sector. It can serve as a tool for evaluation of emerging issues, trends and drivers, as well as real time interaction platform for stakeholders resulting in an enhanced capacity of producing foresight studies that are evidence-based, consistent, credible and properly embedded in decision-making processes.
- Strategic Raw Materials Intelligence entails the production of evidence-based information and knowledge, and foresight studies can enhance this capacity by providing shared visions and alternative images of the future. This report proposes a framework for the setting up of an ‘intelligent’ foresight system.
- As foresight entails longer time frames, methodological recommendations when building alternative images of the future, i.e. scenario development can be drawn by assessing the suitability of the numerous approaches available. Considering past raw materials foresight case studies and the premises of more qualitative approaches, key factor-based techniques for Scenario Development stood out.

DELIVERABLE REPORT

1. Introduction

The MICA (Mineral Intelligence Capacity Analysis) project aims at providing raw materials stakeholders with the best possible information using an ontology-based platform (EU-RMICP), by:

- Identifying stakeholders' groups and their raw materials intelligence requirements;
- Assessing sources of relevant data and information;
- Conducting analyses of appropriate methods and tools; and
- Providing guidelines and policy recommendations.

In that context, the Raw Materials Foresight Guide (Deliverable 5.5) finalizes the efforts of the Task "Strategic Raw Materials Intelligence Approaches" under the Work Package 5 "Minerals Policy Context" of the MICA project. It seeks to place foresight in context to raw materials intelligence, minerals policy-making and the MICA online platform (EU-RMICP), providing guidelines and recommendations for building customised exercises with a special focus on long-term, qualitative approaches, accounting for potential raw materials stakeholders' needs.

This report is structured into four main components:

- **Foresight conceptualisation and methodological approaches**: Basic definitions are outlined, framing the understanding of foresight and setting the landscape for methodological approaches to be later described. It focuses also on the process of designing foresight methodological frameworks according to possible objectives and conditions of the study;
- **Foresight applications**: It brings special attention to policy-oriented foresight and the concept of strategic raw materials intelligence, placing foresight in context and summarising future challenges, trends, uncertainties and driving forces derived from an extensive review of past raw materials foresight case studies.
- **Raw Materials Foresight Framework**: Proposes a framework for foresight studies in the raw materials sector, considering the different stages of the process, objectives and typical themes addressed in the raw materials domain. It seeks to support the visualisation of the foresight concepts against the practicalities of the mineral raw materials sector with a view to the process and possible approaches. Then, it places the framework in the context of the MICA online platform (EU-RMICP), setting it as a reference to support the acquisition of relevant knowledge regarding future-oriented raw materials questions.
- **Recommendations**: The report ends with a summary of recommendations, a raw materials foresight SWOT analysis and the suggestion of future actions that can boost the benefits and improve the practice of Foresight in the raw materials sector.

The guide is directed at members of the raw materials 'world' seeking to navigate and explore the futures of the sector, with a view towards policy- and decision-making. Supporting foresight approaches, methods and tools can lead to the *terra incognita* of the futures, acknowledging the role of strategic intelligence in providing visions and alternative images of the future as well as empirical, evidence-based intelligence. A variety of landscapes can be discovered by setting important references and by discussing relevant aspects to the raw materials sector, foresight and strategic intelligence. Ultimately, it aims at enabling further exploration and designing of raw materials foresight studies.

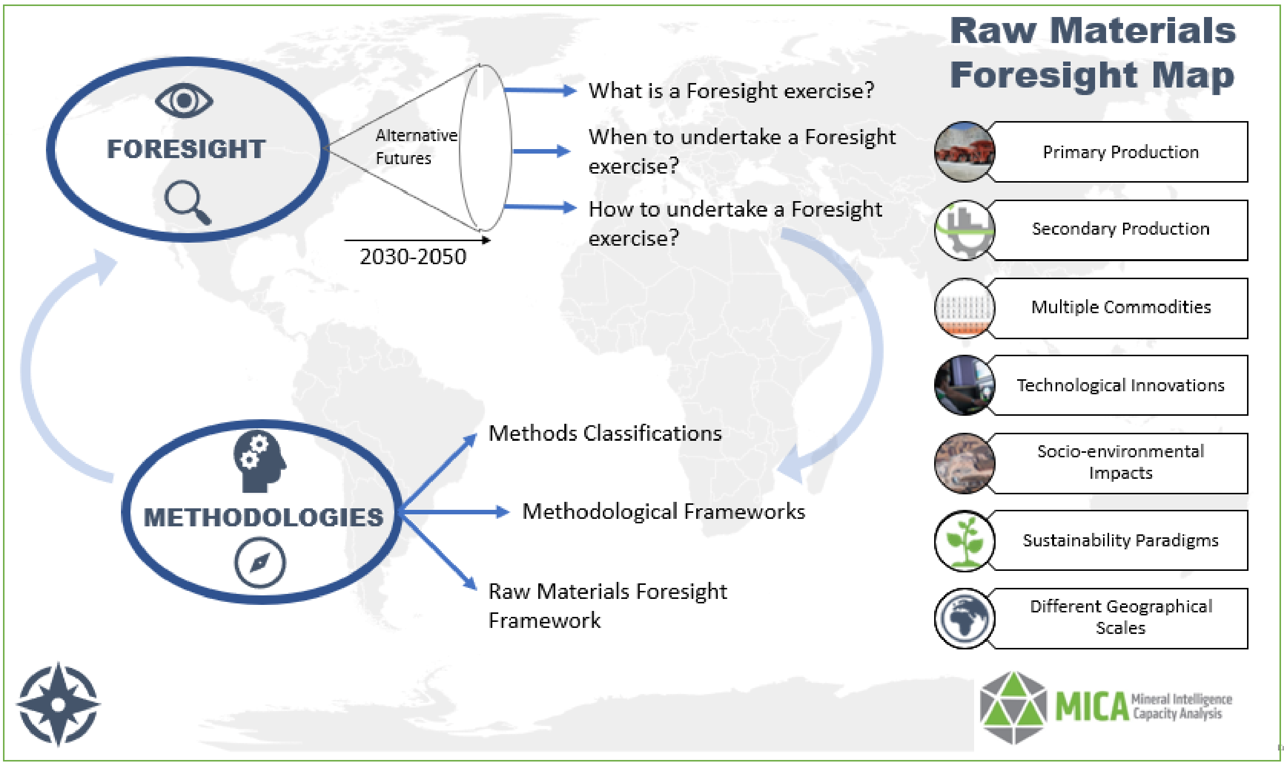

Figure 1 Raw Materials Foresight Map.

2. What is a Foresight exercise?

Many of the unique features of human life, including ethics, technology, and civilization, are directly related to our capacity to be conscious of the future in an expanded temporal manner (Lombardo 2008). Foresight as it will be defined in this chapter emerged after the Second World War as a more explicit attempt in translating this capacity of thinking about the future into a formal, systematic way. With broad goals and under a variety of landscapes it became common in such decision-making contexts as military strategic planning and (French) spatial planning. In later decades, corporations such as General Electric and Royal Dutch Shell introduced Foresight techniques in their corporate planning procedures (Popper *et al.* 2008). From then on, Foresight developed as a widespread practice, with different schools and approaches, addressing issues in a more integrated fashion.

Frequently, foresight focus is directed at national level (Foresight programmes) either society- or industry-focused, though individual companies can also work with foresight for a better envisioning of the future and developing better corporate strategies (Rialland & Wold 2009).

As already observed by the European Foresight Platform (ForLearn, www.foresight-platform.eu/), there is a rising demand for expertise in foresight and forward-looking activities – this demand can be divided into a) strategic planning and long-term decision-making in corporate Foresight, and b) sustainable solutions to Grand Challenges (Giesecke *et al.* 2012) and long-term decision-making.

The report 'A Practical Guide to Regional Foresight' by FOREN (Gavigan *et al.* 2001) defines that "Foresight is a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision building process". It can look at multiple areas, such as science, technology, economy, society, politics, and specific sectors of society. It benefits from involving a broad range of stakeholders in the process and can be used to inform policy-making, build networks, and enhance local capabilities for tackling long-term issues.

More objectively, foresight is not about predicting the future. It assumes that the future is not pre-determined, but can evolve in various directions and can be shaped to some extent by various actors and decisions taken today. These alternative futures can be anticipated, explored and assessed involving actors and stakeholders, who can influence such futures.

Kuosa (2014) suggests five classes of futures domains (Figure 2), placing Foresight in context against different types of approaches. These are defined as:

- **Foretelling and prophesy:** 'Cristal ball' level of understanding of the future – entirely deterministic;
- **Predicting:** Where the focus is on finding strong enough causality relationships that can predict events to a nearly 100% certainty (e.g. some statistical applications in natural sciences and meteorology to some extent);
- **Forecasting:** Attempts to say what is probable and plausible. Based on trend extrapolation, estimations and probabilistic statements;

- **Foresight:** Aims to create a more comprehensive understanding of change in the future, presenting a spectrum of alternative futures instead of just one forecast;
- **Future Studies:** Differ from foresight regarding their objectives. While Foresight helps decision-makers and stakeholders to explore options, Future Studies attempt to envision a better world and make a change towards it.

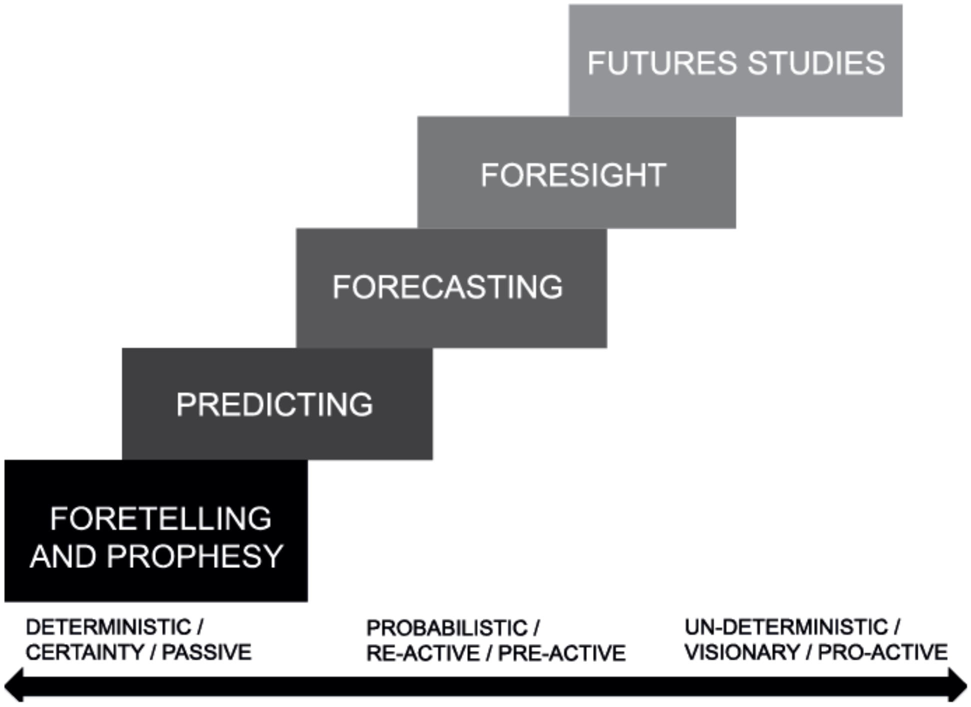

Figure 2 Scale of different classes in futures domain (Kuosa 2014).

The ForLearn online guide outlines that foresight, apart from being a non-deterministic approach, should be:

- **Action-oriented:** not only about analysing or contemplating future developments, but also supporting actors to actively shape the future;
- **Participatory:** it should involve numerous groups of different stakeholders; and
- **Multidisciplinary:** it should be based on the principle that the problems faced cannot be reduced to one dimension.

This can be summarised as a triangle (Figure 3) combining "Thinking the Future", "Debating the Future" and "Shaping the Future".

Keenan *et al.* (2003) argue that foresight has been increasingly used in the last decades for covering different sorts of activities, re-branding of technology watch, environmental scanning, forecasting and similar activities as foresight. The term "fully-fledged" foresight (see Table 6) can be used to describe approaches that go beyond the narrow use of methods in future studies contexts (Figure 4).

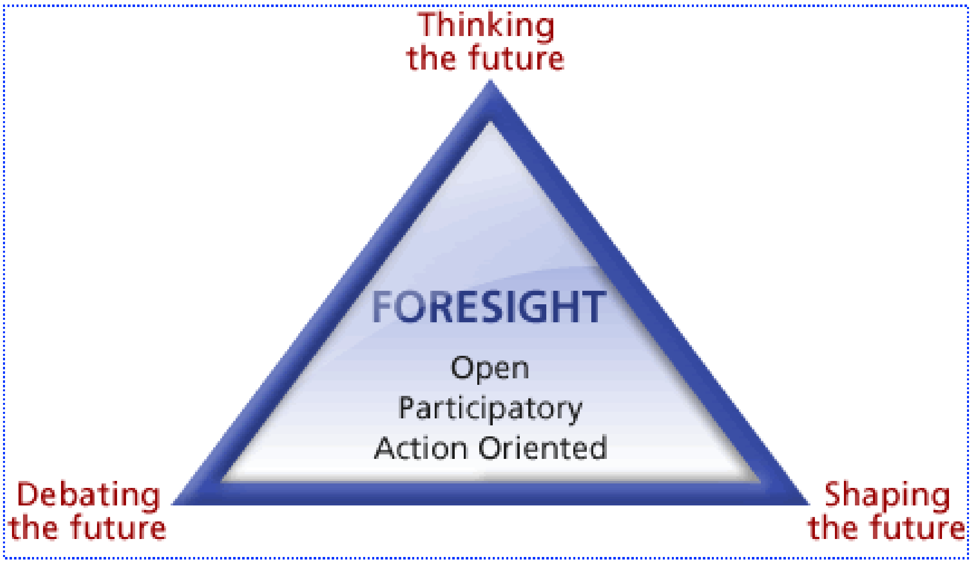

Figure 3 Foresight Triangle (ForLearn. Source: http://forlearn.jrc.ec.europa.eu/guide/1_why-foresight/characteristics.htm).

Several initiatives (see Chapter 7) in the raw materials domain attempted to consider the long-term future of various and/or specific aspects of the sector, tapping into the traditional foresight tools and methods (e.g. Scenarios). Not all steps mentioned in this report must be strictly followed to benefit from the process of Foresight. This report also builds on a raw materials foresight case studies review (Appendix A) which comprised a variety of approaches drawn from case studies featuring foresight methods and tools. This provided a strong benchmark for methodology evaluation, but did not necessarily follow a typical foresight process. Thus, in this report, foresight is to be seen more broadly and in a less strict sense.

Keenan & Popper (2007) outline six main principles that help to define foresight in its broader sense:

- **Future-orientation:** primary assumption that the future cannot be predicted, offering degrees of freedom between possible, probable and preferable futures;
- **Participation:** it benefits from involving a wide number of actors concerned with the issue at stake;
- **Evidence:** although not sufficient in itself, evidence offers reliability and plausibility to explore the futures;
- **Multidisciplinarity:** the increasing complexity of the issues being faced today is increasingly requiring broader perspectives, which in turn benefits from involving different disciplines.
- **Coordination:** as a participatory process, foresight processes mobilise resources and people over the different issues and agendas;
- **Action orientation:** Ideally, foresight exercises should attempt to support the capacity of actors to act upon and shape the future.

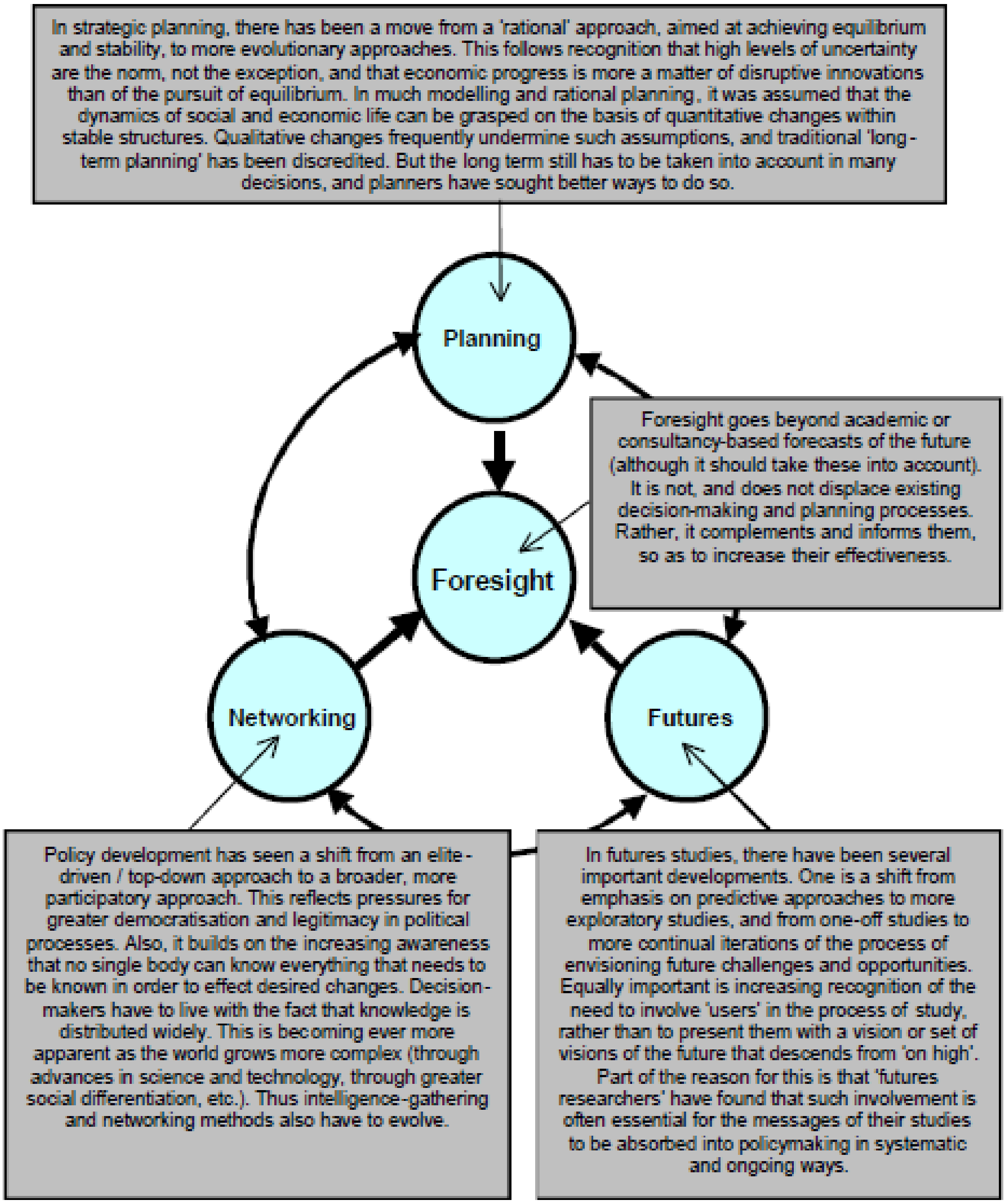

Figure 4 A perspective on fully-fledged foresight (Gavigan et al. *2001, Keenan* et al. *2003).*

Furthermore, Kuosa (2014) in the context of 'Strategic Intelligence' and foresight suggests "three versions of Foresight", which can be divided into:

- **Strategic Foresight:** customer-oriented exercises with well-defined targets. It aims to produce strategically viable alternatives for public (policy-makers) or private decision-makers. It can also include Desk Work and Participatory Foresight as elements within the project.

- **Desk work:** a more academic approach of integrating foresight into a particular research project, planning process or report writing. It tends to have a lower degree of participation and it is less client-oriented;
- **Participatory Foresight:** which refers to a broad involvement and empowerment of stakeholders participating in the process of futures visioning.

3. When to undertake Foresight exercises?

3.1 Identifying initial suitability

There are mainly two dimensions to be looked at when trying to understand whether foresight is the best approach to respond to specific needs: one is related to the comprehension of what foresight can actually deliver – and by extent matching it with the objectives – whilst the second concerns the feasibility of implementing such approach. From this starting point, one can begin to understand that there are key factors influencing the utilisation of a foresight exercise. In Chapter 4, phases of the foresight process will be outlined, identifying such factors according to each stage of the process. Foresight is indicated, when considering longer time frames in the future (>10 years) and a reasonable level of access to resources. Figure 5 illustrates the temporal availability of resources, where the 'Max.' (Maximum) level refers to a total 'operational flexibility' of the foresight approach adopted, wherein virtually all of the constraints and implications can be shouldered. The 'Threshold' level refers to the minimum set of resources necessary to enable the adoption of a foresight exercise.

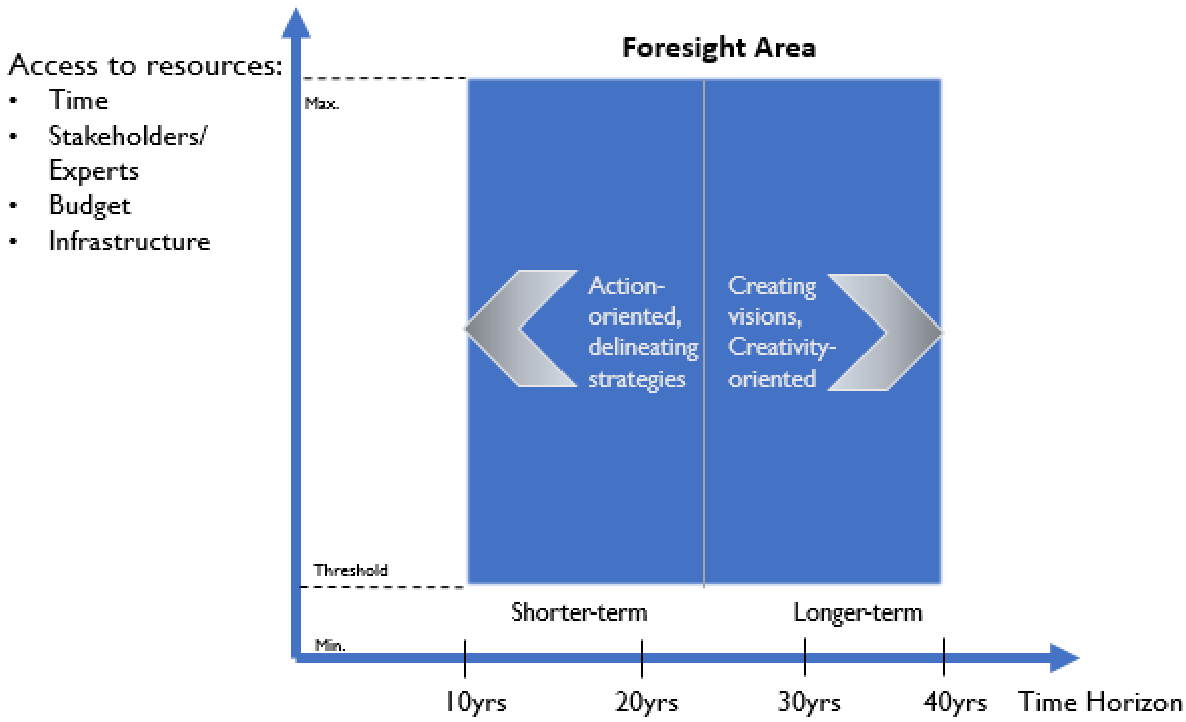

Figure 5 Foresight suitability area – access to resources and time horizon.

Foresight approaches can serve as platforms for providing recommendations in a longer-term future context. As they do not attempt to predict the future, recommendations drawn from the acknowledgment of such conditions are more robust by considering alternative futures or by creating a common vision for addressing a specific issue – thereby better preparing for the different paths and challenges to get there. Foresight, thus, should not be seen as a 'quick fix,' and it cannot be expected to achieve results overnight. There are situations where foresight might not be the best approach, such as when:

- Key stakeholders cannot be actively engaged in the process;
- Time-scales of interest are shorter than 10 years;
- No clear, precise, and agreed scope can be established;
- There is no possibility to act on the results.

3.2 Objectives

Before delving into the range of possible foresight objectives, it is important to define that objectives must be clear, consistent, realistic and ideally not too specific when developing the exercise. As foresight planning is not a linear process, it can be refined during the process (feedback loops) and should involve key stakeholders from the start.

Foresight objectives can be divided into two levels: General and Specific. General objectives are usually concerned with the provision of recommendations (e.g. informing policy making), building networks, developing capabilities and creating shared strategic visions. A variety of specific objectives can be derived from the functional context of the exercise. Some more specific objectives frequently observed are:

- Planning Science & Technology Funding and setting priorities;
- Planning major public spending with long-term implications;
- Influence policy-making with visions of the future;
- Identifying investment opportunities;
- Strategic decisions or defining strategy (company or industry-level);
- Improve quality and effectiveness of policy-making;
- Promoting public debate on future issues;
- Generating preferred visions of the future.

These objectives are transversal to the multiple areas that foresight studies can address. As scoped from the review of raw materials foresight case studies (Martins & Bodo 2017), this report suggests Geographic orientation, Policy-supporting, Sustainability, Research/Technology-oriented and Supply/demand challenges as thematic clusters that are typical targets in this context. The five thematic clusters are explained in more detail in Table 1.

3.3 Preliminary assessments

There are important aspects that have to be considered before and during the planning phase of the exercise. Once the preliminary need for a foresight approach is identified, one must start considering important factors that will sooner or later determine the feasibility of such approach. Moreover, they can indicate, whether the initial approach might need to be re-designed. Such factors are important when the exercise is being scoped and will then be analysed in more detail. They can be briefly summarised as:

- **Time**: Foresight studies are not usually quick exercises to undertake – they may take several months or years;
- **Budget**: as time duration and personnel involved in the project increase, related costs become proportionally critical;
- **Actors involved**: As a participatory process, foresight benefits from involving a range of different stakeholders. Duration of the exercise and methods and tools employed might require adding staff to the project team to manage and facilitate the process.

Table 1 Raw Materials Foresight Thematic Clusters.

Area/Thematic Cluster	Description
Geographic orientation (e.g. 'National Benefit')	Such studies might explore the raw materials sector at a regional, national or even global scale and how to derive long-term socio-economic benefit. Primary extraction of resources affects communities at a local level but also at the level of a country's economy within a global context (e.g. resource curse). Foresight studies can aid strategic understanding of the former, informing companies seeking to better manage potential risks (e.g. Social License to Operate) and help policy makers in both cases assuring an equitable and sustainable wealth creation derived from such non-renewable resources. Some studies can explore global environments linking it to a regional/local context.
Policy-supporting	As mentioned in Deliverable 5.1 (Falck *et al.* 2017), a raw materials intelligence framework is essential for the proposition of a robust minerals policy. Foresight is an important component of such approach bringing long-term perspectives for policy-making.
Sustainability	At both a policy-making and corporate level, the raw materials sector historically dealt with environmental issues as well as specific socio-economic impacts. With Sustainable Development becoming a mainstream target and the emergence of paradigms, such as climate change combat, resource efficiency and circular economy, these can be objects of Foresight studies, helping to adjust policies and company strategies according to the different future perspectives.
Research/Technology-oriented	Primary and secondary production of raw materials are strongly impacted by technology breaks. Therefore, it is of strategic importance to understand how disruptive technologies can shape the future in a particular context as well as identifying gaps and future research needs in specific areas for tackling potential emerging issues.
Supply/demand challenges	Foresight studies can also focus on the futures of a single mineral commodity in the context of a company's portfolio or at a policy level considering the importance of that single product to the specific nation or region's economy.

A broader assessment of the main factors is presented in the scoping phase of the exercise (see Section 4.3). These conditions can be assessed in terms of the level of choice, that is how flexible the definition of these factors is. Conditions are, thus, factors that are more rigid in their scope, whereas more flexible factors – more malleable for the project manager – are the exercise's modulators. Some of these factors are featured in Figure 6. On the left-hand side tend to be condition setting. By contrast factors on the right-hand side provide project managers with greater capacity to modulate their activities around these elements.

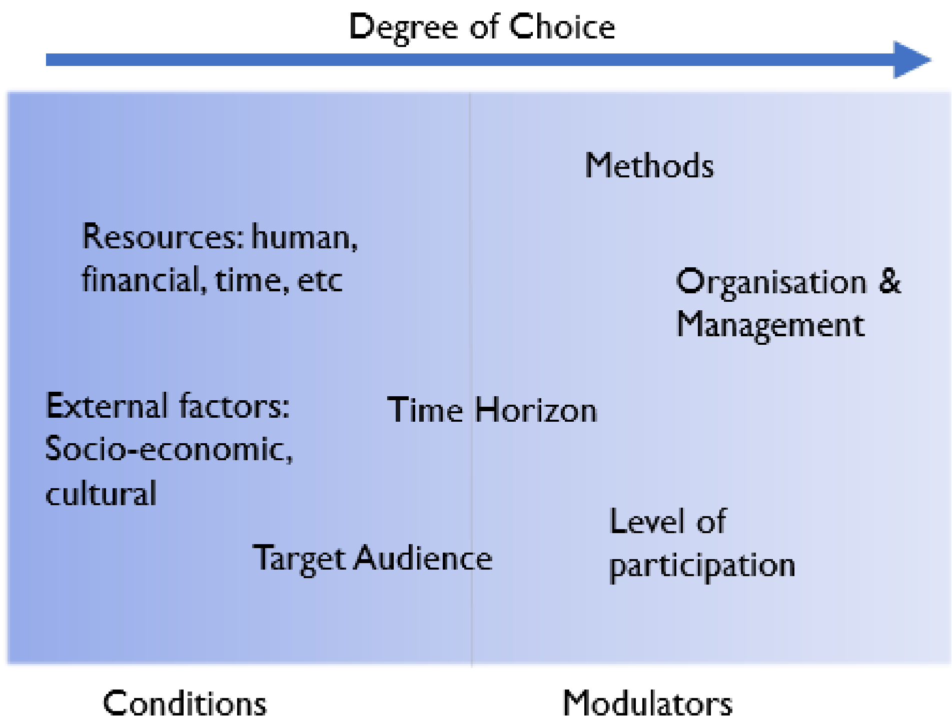

Figure 6 Degree of manoeuvre associated with foresight planning factors (adapted from Keenan et al. *2003).*

For the policy-making case, additional factors have to be considered, such as:

- Identification of the decision-makers and government bodies that might be influenced by the process;
- Identification of government bodies that can act upon the results;
- Identification of the types of input feeding the process of decision-making and at which stage it will be relevant.

4. How to undertake Foresight exercises?

4.1 Foresight Guides – References

There is no single best approach on how to develop a foresight process. Few attempts have been made to produce 'Foresight Guides', setting the basis on how to proceed successfully with a foresight study. Typically, they do not focus on raw materials or related sectors, but provide a more general format of 'Foresight Guiding'. These guides largely constitute an overview over the general foresight processes, phases and methods and respective tools available. They may be complementary sources to this report as they may provide more details on the topics covered here. This report will focus on providing foresight guidelines pairing it with the raw materials intelligence context. Table 2 presents an overview of the main European sources in this context:

Table 2 Foresight Guides.

Title	Author/Reference
FOR-LEARN Online Foresight Guide (2007)	JRC – Joint Research Centre (European Commission)[1]
European Foresight Platform (EFP) – ForLearn Section (2010)	European Foresight Platform – FP7 Project (244895) – 2009/2012[2]
A Practical Guide to Regional Foresight (2001)	FOREN – Foresight for Regional Development Network Gavigan *et al.* (2001)
Frame: Skills for the Future – Foresight Guide (2014)	European Training Foundation (ETF, 2014)
Handbook of Knowledge Society Foresight	European Foundation for the Improvement of Living and Working Conditions (2003)[3]

4.2 Foresight Phases

Popper (2008) suggests that the process of foresight development can be divided into five complementary phases:

- **Pre-foresight (Scoping)**: to define objectives, project team and design methodology;
- **Recruitment**: additional members can be incorporated, e.g. key knowledge sources and practitioners can be identified;
- **Generation**: generating new and integrating existing knowledge in the system. Exploration of main issues, trends and drivers, analysing how they influence one another. Anticipating possible futures or suggesting desirable ones.
- **Action**: to ensure that foresight informs decisions; and
- **Renewal**: the constant monitoring and evaluation assessing the effectiveness of the foresight process.

[1] URL: http://forlearn.jrc.ec.europa.eu/guide/0_home/index.htm
[2] URL: www.foresight-platform.eu/community/forlearn/
[3] URL: www.eurofound.europa.eu/publications/2003/handbook-of-knowledge-society-foresight

Different sources can provide slightly different variations in terms of defining the stages of the foresight process (e.g. ForLearn, European Training Foundation). For the purpose of this report, these different stages will be described in some more detail as:

- **Scoping phase**: comprising the definition of the focus, objectives, users, outcomes, purview, approach, time horizon and timeframe. Furthermore, these factors should be feasible (feasibility assessment). The scoping phase can also produce a planning document of the foresight exercise with the methodological design (framework) of the exercise, i.e. which and how foresight methods will be used and combined;
- **Development phase**: securing sources of data and knowledge. It details the actual stakeholders and experts that will be involved, the actual schedule for the exercise in the given timeframe and systematically communicate on the developments to the targeted audience. Ultimately, it ensures the process of transforming it from a planned exercise into a running exercise producing relevant outputs and outcomes; and
- **Evaluation**: proxies for monitoring both direct and indirect impacts and outcomes of the Foresight exercise once finalised.

Figure 7 provides an illustrative flowchart summarising these phases and steps in the raw materials context.

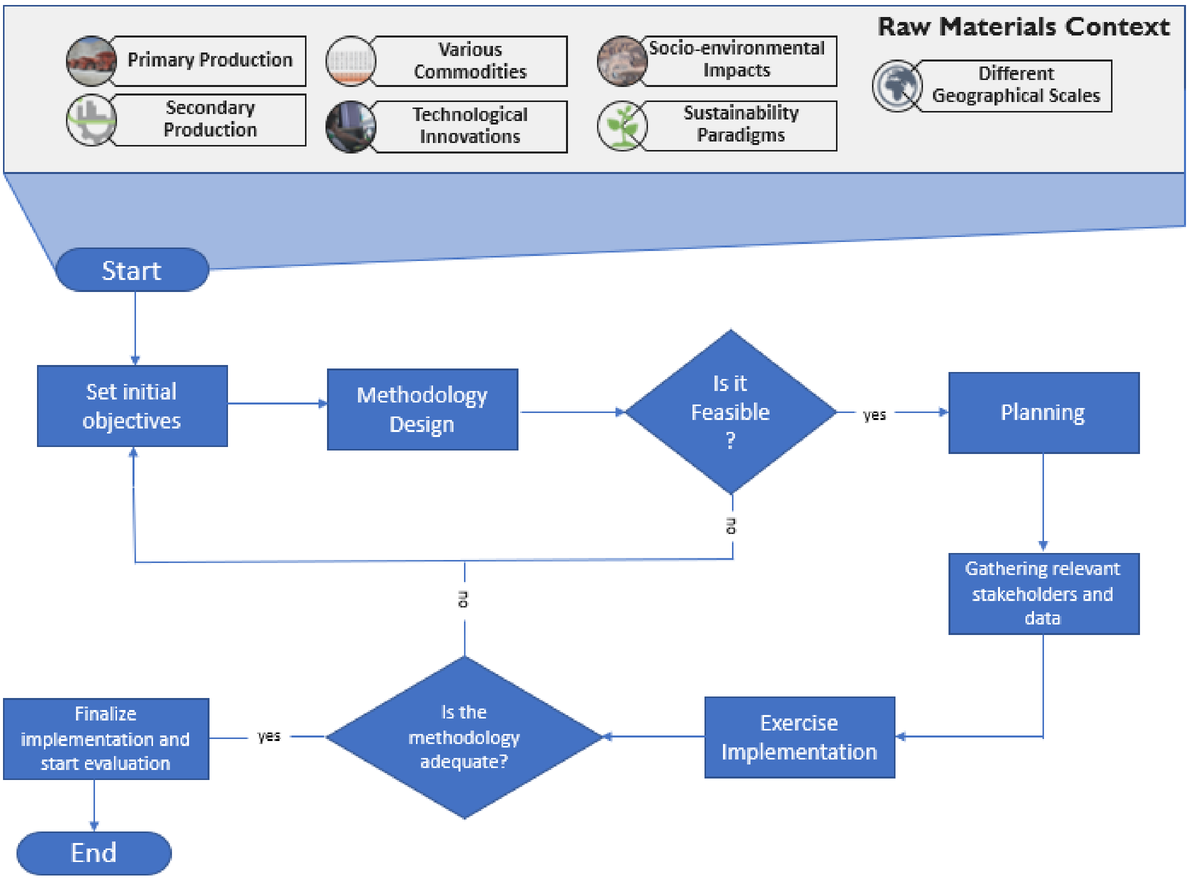

Figure 7 Foresight implementation flowchart.

As can be observed, the selection of methods and the design of the methodological framework are crucial parts of any foresight exercise. With the aim of providing useful guidelines on raw materials foresight methodological approaches and methods, later sections of this report (Chapter 5 and 6) detail such topics. Figure 8 sets related background definitions.

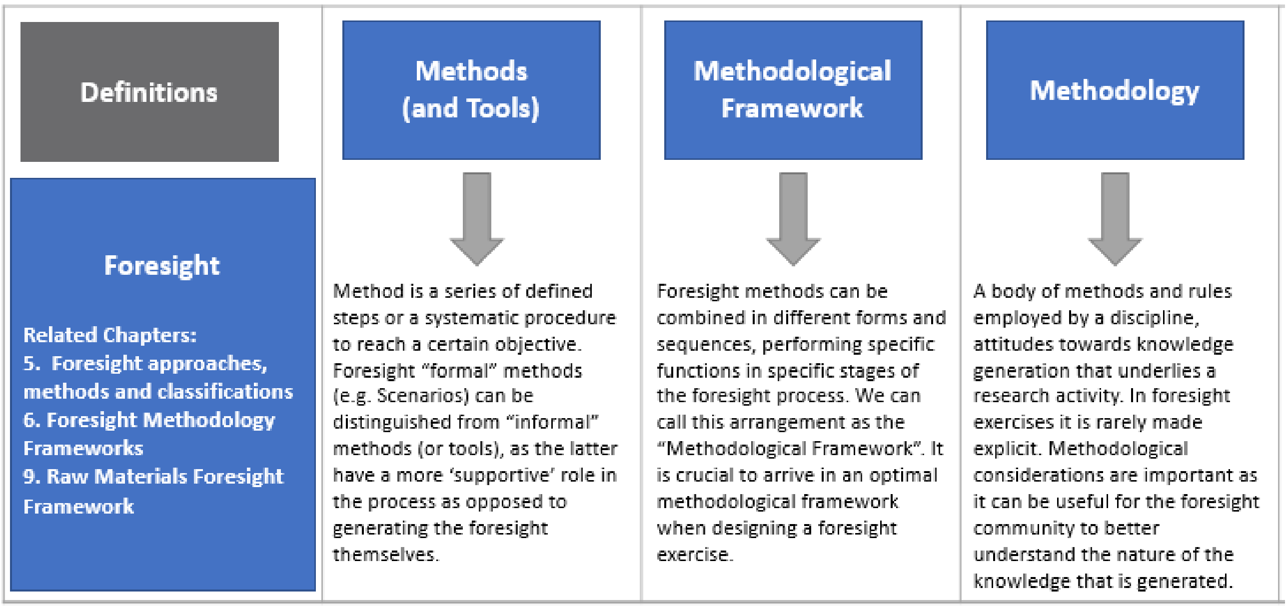

Figure 8 Foresight definitions: methods, methodological framework and methodology (adapted from ForLearn).

4.3 Scoping

4.3.1 Introduction

Scoping an exercise typically starts with setting of initial objectives. The exercise, however, can evolve into different directions from what was originally planned. It is not a linear process: it relies on constant evaluation of the progress thus informing the further planning and adjusting the procedures according to the needs identified.

Scoping an exercise comprises the definition of the following main elements:

- **Definition of general parameters**:
    - Focus;
    - Objectives;
    - Users;
    - Perspective to be adopted;
    - Approach;
    - Time horizon;
    - Time-frame
    - Design of foresight methodological framework;
    - Feasibility assessment;

- **Feasibility**: matching the desired impact on the system addressed with the available resources;
- **Planning**: structuring the organisational side of the exercise: definition of actors involved (project team, steering committee, experts and stakeholders, as well as a communication strategy);
- **Designing the methodology**: which initially is defined in function of objectives and desired outcomes, but can also be adjusted as the exercise progresses.

Considering the above-mentioned challenges and acknowledging time as a critical aspect of the foresight exercise, it is important to plan for delays. Spin-off activities might enhance the quality of work, but they should not distract from the overall focus of the project. The more sophisticated and resourceful the foresight project is, the more complex it becomes to manage both, the process and time. It is critical then to evaluate the management level of the exercise in accordance with its size. Smaller exercises might be easier to manage and carry out. However, absence of key participants in such cases can be harmful to the process.

The implementation of a foresight exercise might involve numerous meetings (virtual and in presence), workshops, surveys, among other aspects. When designing the methodological framework, one must be aware of the (infra)structural implications that certain methods and approaches might have. Such implications can range from the time required to budgetary aspects, e.g. online meetings can substantially decrease the costs when compared to having participants flying in from distant locations to meet in expensive venues – this, in turn, can decrease the level of interaction of these participants in the process.

ForLearn summarises key points to bear in mind in this stage of the foresight planning:

- **Build on existing materials**: when there is plenty of relevant material available, the foresight study could tap into e.g. existing scenarios to be explored, or work-over published SWOTs for competitiveness analysis in a sector environment;
- **Cost**: each method's description provides hints of how resource-consuming they are. Choosing a sophisticated method without making sure that there are resources available can be very harmful to the foresight process.
- **Availability of participants**: as some methods are heavily reliant on experts and engagement of stakeholders, it requires a good evaluation of which level of participation for the study should be secured. Such evaluation must be undertaken before the method is chosen and employed;
- **Time**: some methods are time consuming. The planned timeframe of the exercise should be well synchronised with the application of the methods and their respective time requirements.
- **Skills**: each method requires certain competencies – ranging from meeting facilitators, text writers to computer programmers. Before selecting a method, it is crucial to assess, whether such competencies are available or can be brought into the project.

A checklist of the items that should be considered (and addressed) by the end of this phase can be seen in Table 3.

Table 3 Scoping phase checklist (adapted from Kosow & Gassner 2008).

✓	What is the overall goal of the project?
✓	Who is commissioning the project and who are the stakeholders?
✓	Whom should the project's outputs reach?
✓	Is the focus more analytical or interactive?
✓	Are there normative aspects?
✓	Are quantifications required?
✓	What is the Foresight methodology approach and how is it going to be applied?
✓	How much time is available?
✓	What is the available budget?
✓	Is there enough knowledge available internally and/or should it be externally provided?
✓	What is the extent of possible access to stakeholders and is external knowledge needed?
✓	What is the geographical coverage of the study?
✓	What is the time horizon?

4.3.2 Focus

Foresight exercises can focus on specific issues or thematic fields. In the raw materials domain we can identify different thematic clusters (described in Table 1) with subsets of specific issues. Large-scale (fully-fledged) foresight exercises, for instance, might deal with multiple issues from different thematic clusters. They can be grouped into three levels:

- **"Scalable" level:** comprising geographical coverage:
  - International or multi-national;
  - EU (Supranational);
  - National;
  - Regional;
  - Local;

  and sectoral coverage, which can range from a single commodity to an analysis of the whole sector (e.g. "Mining & Metals");
- **Production level:** where the study can focus on primary production and/or secondary production of raw materials; and
- **Framing level:** which can narrow – or not – the focus to specific themes and interactions. It can potentially present a normative component for the foresight exercise (see section 5:
  - Technology-focused;
  - Social and environmental impacts;
  - Resource efficiency, energy efficiency, climate change and circular economy and other potential sources of paradigms shifts.

Any raw materials foresight focus could be categorised by a multiple combination of these levels and elements. Figure 9 and Figure 10 illustrate the raw materials context.

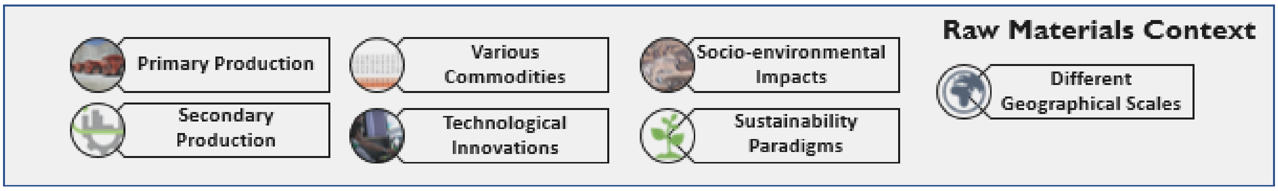

Figure 9 Raw materials foresight main contextual elements.

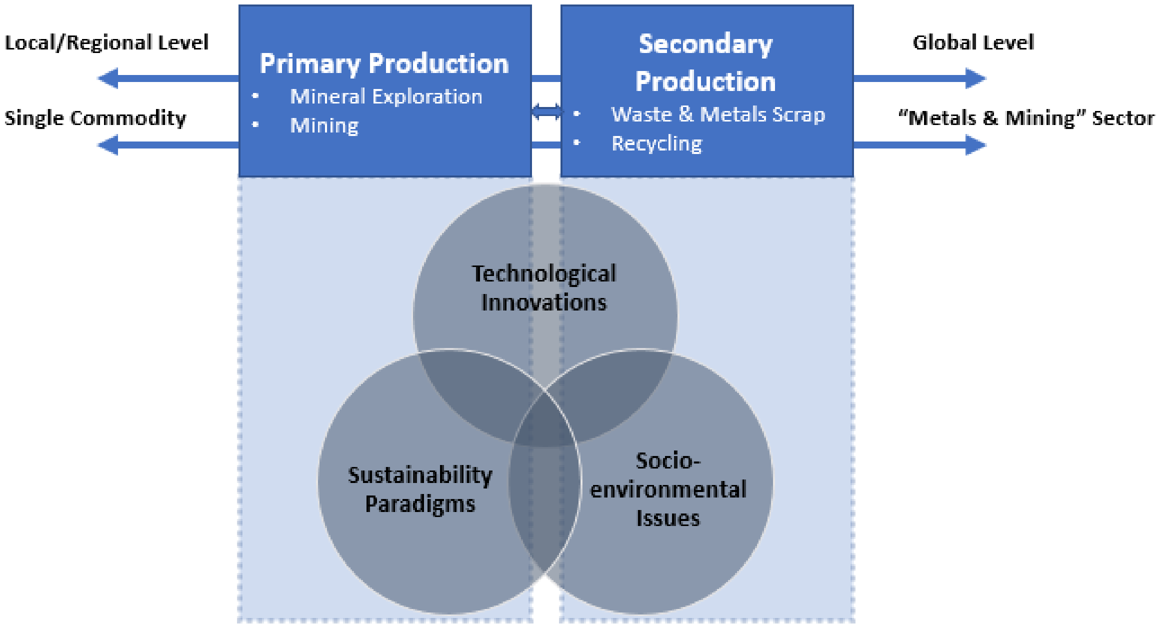

Figure 10 Three-level raw materials context.

4.3.3 Objectives

As introduced in section 3.2 there can be a wide range of objectives in foresight exercises. Defining the objectives is largely linked with the feasibility of the exercise, as objectives must be realistic and entail achievable results.

Typically, three main factors should be considered when defining the exercise objectives:

- **Timing:** the earlier objectives are stated the smoother the development of the exercise will run. However, there should be room for timely adaptation during the development of the exercise. Practical details later on in the process (e.g. budget availability, time etc.) can render constraints to the initial objectives, and thus require additional iterations.
- **Interaction:** Being too specific on the definition of the objectives from the start can jeopardise widespread public support for the exercise at the early stages. Ideally, objectives must be debated between the key players involved in order to ensure early buy-in to the exercise. This involvement of actors can be an objective in itself. It is important that the objectives reflect the linkage of foresight to actions.

- **Communication:** The objectives must be clearly stated and communicated to the participants and stakeholders throughout the exercise. They should be readily understandable and internally consistent.

Kuosa (2014) adds seven main clusters of general objectives:

- **Political views:** the attempt to influence policy-making with one's views or opinions;
- **Strategy selection**;
- **Identifying viable options:** for bottom-up and top-down;
- **Risk detection:** main objective of early warning systems and intelligence functions;
- **Empirical research:** environmental scanning (i.e. Horizon Scanning), time series analysis and statistical functions;
- **Participatory assessment:** through interaction-based methods;
- **Creating visions and studying values**.

Overall, the definition of the objectives and the emphasis put on them will directly inform the methodological choices and approaches. Notwithstanding, the objectives will serve later as a reference for the evaluation of the exercise.

4.3.4 Users

In general, foresight users can be divided into sponsor/clients and stakeholders. While the former are rather obvious, the identification of the latter in a comprehensive manner can be challenging. A clear understanding of potential users is of great importance as it can help the definition of the exercise in a way to maximise the benefits. Table 4 provides an overview over potential users of foresight, according to generic foci.

Table 4 Potential Foresight Users (adapted from ForLearn online guide).

Foresight Focus	Social Issue	Technological Issue	Sectoral	Territorial view
Potential Foresight Users	Policy makers	Policy makers	Policy makers	Policy makers
	Consumer associations	Universities	Industry	Territorial Associations
	Knowledge infrastructure	Research organisations	Chamber of commerce	Trade Unions
		Industry	SMEs	

As was observed in Martins & Bodo (2017) there is a wide range of different users of foresight in a raw materials context. This guide suggests three categories of user profiles, classified by their background, level of foresight expertise and focus (Figure 11). For information of approaches on stakeholders' identification see section 4.4.

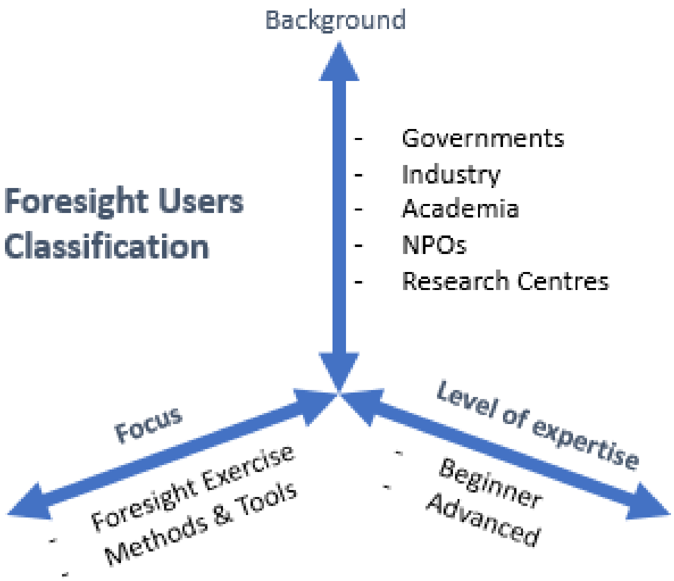

Figure 11 Raw Materials Foresight Users Classification.

These categories can be summarised as:

- **Background**: related to the context of the client (or user), which in turn determines what possible objectives it might have, what kind of resources might be available and ultimately informs the Foresight process itself from planning and design stages to the evaluation;
- **Level of foresight expertise**: while newcomers to foresight might be more concerned with the Foresight process itself, how to plan and design the exercise, more advanced users may focus on specific characteristics of the sector and the context where the exercise will be undertaken as well as identifying appropriate data and knowledge sources;
- **Focus**: this relates to the approach of the client (user) to the foresight process. As some might 'skip' the step of formally going through the foresight stages and focus more on the typical methods and tools available. Scenarios Development, for instance, is frequently treated as a core part of the exercise, which may tend to steer the overall process instead of a pre-planned structured foresight study.

4.3.5 Outcomes & Outputs

As objectives are defined, the desired/likely outcomes of the foresight exercise can be better understood and shaped. This can be done by delineating tangible and intangible outcomes (Table 5) and relating these to the user groups. This definition entails an understanding of the users' needs, the set objectives and the specific context in which the foresight exercise is being carried out.

Intangible (or informal) effects of foresight can be, for instance, outcomes during the process of foresight that cannot be formalised as deliverables. Networking, consensus on future challenges, cultural development, development of a 'foresight culture' by participants and organisations, changed attitudes and mindsets are examples of foresight elements that pertain to the realm of intangible outcomes. Tangible outcomes, on the other hand, may include explicit repercussion such as citations and press articles.

Table 5 Tangible vs. intangible outcomes of foresight (ForLearn).

	Tangible outcomes	Intangible outcomes
Dissemination	*Citations, press articles*	*Results and evaluation circulating within networks and use as 'baseline' for new studies*
Networking	Institutionalisation of networks	Development of new networks or new links within existing ones
Strategic process	Formal incorporation of results within strategic processes	Informal incorporation of results within strategic processes

Typical elements of foresight outputs can be summarised as:

- Scenario descriptions;
- Survey results;
- Sectoral analyses;
- Critical technology lists;
- Technology priority lists;
- Technology roadmaps;
- Policy recommendations.

The outcomes present an important variable for ex-post evaluation of an exercise. One would typically evaluate if the foresight study outputs have been translated into actions (see section 4.5), which then in turn result in (the desired) outcomes. There may be, however, a significant delay between the formal delivery of the outputs and any measurable outcome that may often amount to years. This can hamper a fair evaluation of such studies, since outcomes are usually beyond the control of those undertaking the studies.

4.3.6 Perspective

The perspective adopted for a foresight exercise relates to how the topics covered are approached or tackled. In general, there are three main perspectives used in:

- **Confined perspective:** focusing on one aspect of the topic;
    - Example: "Identify and prioritise technologies for the management of mine waste of strategic importance for Poland in the next 20 years".
- **Techno-economic perspective:** emerging business opportunities within a given field.
    - Example: "What are the promising future technologies to recover metals from waste?"
- **Holistic perspective:** social/cultural, economic and technological factors and their interactions are addressed as a whole.
    - Example: "Vision 2040: Mining, minerals and innovation – A vision for Australia's mineral future."

It is important to acknowledge that often, due to the different stakeholders' interests and the difficulty of discussing issues in an integrated way, adopting a holistic perspective can be very challenging. The dialogue between different communities and actors in a foresight exercise needs to be carefully managed so as to achieve solid and converging results. Although adopting a holistic perspective is frequently desirable, it might not be necessary as the approach adopted should match the objectives defined to achieve the intended outcomes. In essence, the exercise focus and the topics covered have to be combined with the perspective in an integrated and consistent manner. This will also inform the definition of a suitable foresight method to be used.

4.3.7 Approach

There are two opposing approaches for designing a foresight process:

- Top-down: more formal approach and use of methods. Tends to be smaller in terms of number of participants and therefore places little stress on interaction. It puts a strong focus on experts and collection of information from a wide range of sources. However, this tends to be processed by a small expert group.
- Bottom-up: focus on interaction. The overall process – from information gathering to dissemination of the results – is more subject to discussion between stakeholders, securing more legitimacy and 'ownership' of the activity (Keenan *et al.* 2003).

4.3.8 Time Horizon

As defined in previous sections foresight exercises look at longer-term futures. The time horizon can typically range from 10 to 40 years into the future and is primarily defined by the type of subject under study, the context and the objectives. Some specific criteria can help the definition of the most suitable time horizon for the exercise:

- **Context:** the public sector may vary its focus between shorter and longer time horizons. In the private sector, as the normal planning of a product or service is one generation, a foresight exercise can consider two generations as time horizon.
- **Focus:** in exercises that are more action-oriented, shorter time horizons are more appealing (e.g. 10 years). As the rate of technological change increases, for instance, more pressure can be put on bringing time horizons to a shorter basis. In the case of setting future visions, or more creativity-oriented foresight exercises, longer time horizons become more meaningful to explore (>20 years),
- **Schedule of decisions:** when drafting a strategy, the means to implement it have to be considered. This can inform the definition of which time horizon is more compatible with the given conditions for decision-making (e.g. financial budget already allocated, rigid commitments for shorter time scales etc.).

4.3.9 Time-frame

Foresight studies can last a few months or even become continuous activities (Table 6). In general, circumstances where the subject is narrow might suggest shorter exercises. Ongoing foresight activities might be seen as an ideal target in many circumstances, both in the public and the private sector. However, having resources and time available are the main constraints to implement continuous foresight processes. Typically, foresight units or working groups can be assembled seasonally to set up regular exercises. Reasons from shifting from one-off exercises to continuous foresight activities can be summarised as:

- Reports might be increasingly seen as out-of-date or even irrelevant;

- Networks forged might decay, turnover of people involved can decrease foresight long-lasting outcomes;
- Foresight skills can grow rusty or previous experience 'becomes lost';
- New issues might emerge and call for a re-assessment of previous foresight exercises.

Table 6 Scales of foresight exercises (adapted from Keenan & Popper 2007).

Scale	Description	Duration
Punctual	Mini Exercises (e.g. success scenario or visioning workshop)	1 to 2 months
Small	Focused with a small number of methods (sectoral, thematic or problem-oriented)	3 to 6 months
Medium	Focused & multi-method (sectoral, thematic or problem-oriented)	6 to 12 months
Large	Fully-fledged (multi-scope)	1 to 3 years
Continuous	Foresight programmes and permanent observatories (many exercises including fully-fledged ones)	Ongoing

Due to the variety of context and objectives, raw materials foresight studies could fall into any scale range.

4.3.10 Methodological Framework

Designing the methodological framework of a foresight exercise requires a good comprehension of the foresight methods and tools available, their classification and possible approaches. Many factors impact the definition of methods and tools to be used and how the framework should be constructed (how the methods can be combined). These are largely related to the factors described in the previous sections, although there can be some additional issues affecting this stage of the process. For instance, many methods and tools can be used with the same objective and the actual selection can be related to the foresight practitioners' skills. As some methods are relatively easy to implement, they can become more appealing for newcomers to foresight, while methods requiring more specific skills (e.g. computer literacy and modelling) might require additional efforts, if the project members involved are not used to such approaches. This issue, however, can be curbed by either hiring foresight practitioners according to the expertise required, or by training project members accordingly – the latter being more time-consuming.

Overall, the methodological framework definition is an evolutionary process. It is about finding the appropriate sequence and combination of methods in function of all the above-mentioned factors and constraints. Monitoring the alignment of the methodological framework with the development of the exercise is important to adjust the utilisation of the methods throughout the exercise so as to improve the exercise in line with its evolution.

Foresight approaches, methods and tools are discussed in more detail in Chapter 5. Foresight methodological frameworks are outlined in more detail in Chapter 6.

4.3.11 Feasibility Assessment

The feasibility assessment should occur as the previously described factors are scoped and resources – people, time and budget – are about to be substantially committed in order to undertake the exercise. Such assessment enables the identification of the level of resources needed to carry out the exercise as scoped and whether it needs adjustments. In sum, it marks a decision point whether to proceed, adjust, or cancel the foresight exercise.

In financial terms Keenan *et al.* (2003) suggest that the costs are most likely to come from:

- Running of a project management team;
- Organisation of meeting and events;
- Dissemination;
- Operation of surveys;
- Other routines associated with an exercise.

4.4 Development

At this stage and as the previous steps have been completed, the 'project management' of the foresight exercise shifts its focus to practical aspects such as managing people, time and implementing the exercise through the deployment of the methodological framework defined in the previous phase.

Monitoring the process is crucial to make sure that the developments are in line with the targets previously defined. As foresight is about intelligence-gathering, the knowledge arising from the participation of the various experts and stakeholders might implicate re-direction of the original view of the exercise. It is important to allow for incorporation of changes during the process. Such changes can impact several parameters, including the methodology design, so it is fundamentally related to the participatory nature of foresight to keep an eye on the two following challenges:

- **The evolutionary nature of foresight – and its constant need of assessing adaptation:** new demands from participants might emerge during the exercise and the needs of the client can evolve/change. Also, unexpected constraints can arise, requiring adjustments to the factors previously scoped;
- **Preserving the learning effect:** foresight is also about learning about different topics, perspectives and about interaction and participation. Thus, it requires appropriate strategies for maximising this learning effect, turning it into a benefit for the exercise in itself. Developing a good communication strategy enables the outreach of the project and makes outputs available to a wider audience of potential stakeholders than those immediately involved in the project and thus ensures the raising of awareness of the project's objectives. Actions such as regular updates to stakeholders, dissemination of primary and final results, collection of feedback and networking with other exercises, as well as newsletters and participation in related events can be important for defining a strategy. This will ensure the wider uptake of the results, help the process by facilitating recruitment of relevant stakeholders and experts, and funding, avoiding misconceptions

among the targeted audience on the project's objectives and the general promotion of the exercise.

As a participatory exercise, foresight requires a successful engagement of the participants. Mapping and securing relevant stakeholders and experts can be challenging, especially in situations where they are 'external' to the process (or organisation), that is to say, there is a more acute need for 'convincing' such actors to get involved in the process. Moreover, the level of engagement of participants has to be defined. Stakeholder profiling can be an initial step in obtaining an overview of aspects such as:

- Socio-cultural clustering of individual stakeholders and representative organisations (trade unions, research centres, industry associations etc.);
- Public-private and academic clustering;
- Mapping of power-interest relationships;
- Level of expertise; and
- Level of know-how about the foresight process.

In the context of raw materials intelligence, the MICA project undertook a comprehensive stakeholder analysis in order to further understand potential stakeholders' needs (Erdmann *et al.* 2016). See Appendix B MICA Stakeholders Classification – Raw Materials Intelligence.

Stakeholder identification methods – Examples

Skill/will Matrix

This method can provide a good starting point when identifying possible participants for a foresight exercise. It is based on the assumption that the participation of organisations is driven by two major aspects:

- Skills to act on the strategy; and
- The will to participate.

These two dimensions can be plotted as a matrix, leading to four strategic quadrants (Figure 12).

Laggards: organisations lacking skills to participate and not willing to participate will be reluctant to get involved in the strategy – they will act as followers and should not be involved;
Defendants: Organisations want to preserve the present situation – special attention should be given to possible opposition;
Supporters: organisations willing to participate to enable the innovation, but are lacking the skills (e.g. financial capacity), should be involved in the strategy as supporters;
Champions: organisations that can have a leading role, as they are positive towards the changes suggested and have the skills to make it happen.

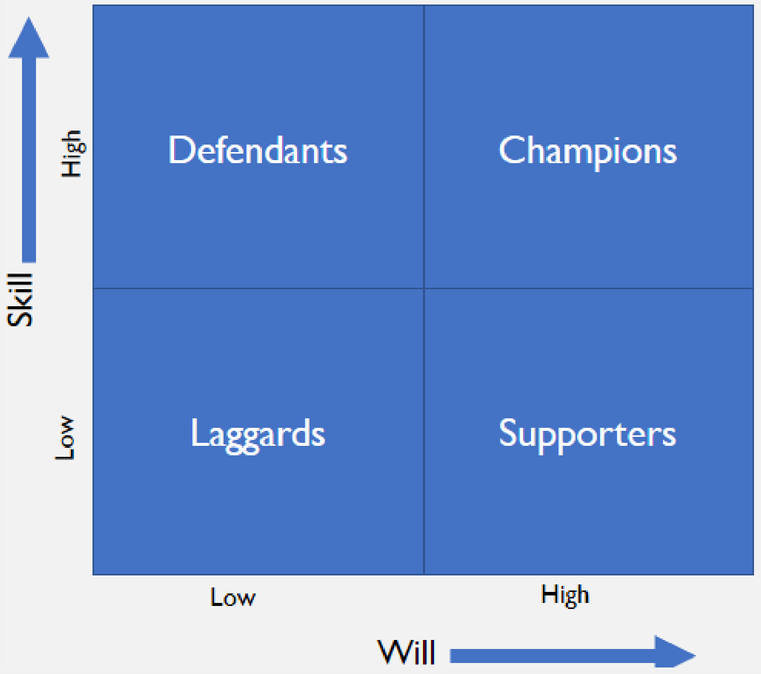

Figure 12 Skill/will matrix.

The next step is to set indicators according to the context of the exercise for detailing these groups.

Theory of Stakeholder Identification and Salience (Mitchell *et al.* 1997).

Mitchell *et al.* (1997) distinguishes three main stakeholder attributes (Figure 13):

- **Power:** a party has or can gain access to coercive, utilitarian and/or normative means to impose its will in a relationship;
- **Legitimacy:** it is attained in the social system by the pursuit of a desirable social stake, negotiated at different levels of social organisation and broadly shared;
- **Urgency:** it can be attributed when there is both time sensitivity and claims or relationships that are perceived as highly important.

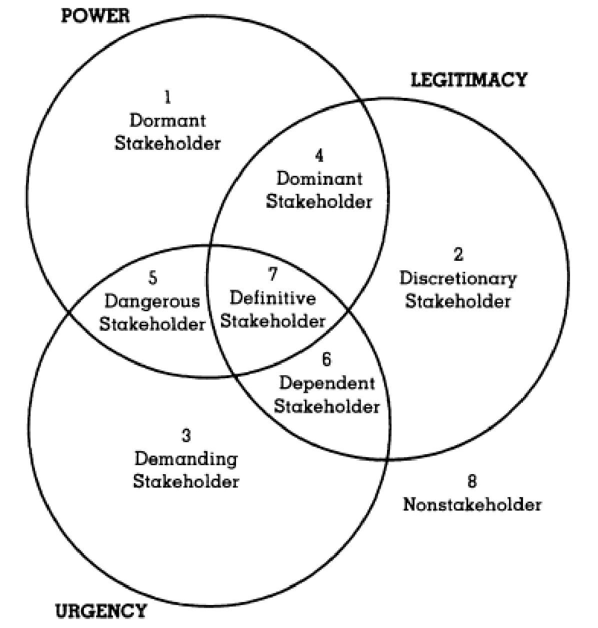

Figure 13 Stakeholder Typology: one, two, or three attributes present (Mitchell et al. *1997).*

The actual 'Foresight' work starts usually with the gathering of relevant data and contextual aspects of the area under analysis, such as reviewing previous work and getting acquainted with the main particularities of the subject, for instance through relevant data sets and reports. This can provide several benefits in facilitating the development of the work – exercises and outputs; foresight portals (e.g. EFP[4]) and the Raw Materials Intelligence Platform (EU-RMICP[5]) are good examples of such sources. In Table 7 a checklist for the development phase can be seen.

Table 7 Development phase checklist (adapted from Kosow & Gassner 2008).

✓	Does the development require external support?
✓	Who is to actually participate in the process in terms of quantity, areas of competence, diversity of experts, stakeholders?
✓	When (at which point exactly) and in what form (workshops, surveys, etc.) is the participation to be taking place?
✓	How is the process going to be organised (workshops, meetings, scheduling, deadlines etc.)
✓	Are data requirements covered (by experts, paid acquisition, internally available etc.)

4.5 Evaluation

A systematic reporting from people involved in the activity is a typical example of evaluation of the foresight outcomes. It should be broad enough to account also for unexpected benefits, capturing the immediate and longer-term ones. As benefits can be experienced at different levels, a survey for such evaluation needs to be framed so as to capture these different types of benefits.

[4] The European Foresight Platform provides 'policy briefs' of foresight exercises as well as a database on forward-looking activities (FLA Mapping). Website: www.foresight-platform.eu/
[5] To be launched in January 2018.

Scheduling post-exercise surveys can have a shorter-term focus, e.g. on general impressions over the exercise, and a longer-term focus e.g. on how the exercise may have (a posteriori) influenced decisions made. The focus will of course depend on the context and expected outcomes previously defined. More general examples of potential benefits might include:

- Are there improved linkages between the stakeholders in the system addressed? This can be assessed by querying participants directly regarding their experiences;
- Have new activities or initiatives been undertaken, and priorities shifted as a result of foresight?
- Is there evidence of the creation of a 'Foresight Culture'? Is there evidence of the results of Foresight being discussed within users' organisations?

Johnston (2012) suggested a 'Foresight Impact Evaluation Scheme' (Table 8) attempting to classify and summarise previous experiences and guide a more effective impact assessment on foresight studies. However, each specific Foresight study would require a customised application of such framework.

Table 8 Foresight Impact Scheme (adapted from Johnston (2012)).

Type of Impact	Outcome	Possible Metrics
Awareness raising	• Increased consideration of issues with longer time horizons in planning and decision-making. • Overall increase of foresight awareness at all levels, sectors and actors.	• Extent of reported use of foresight. • Recognition and recruitment of foresight skills. • Proportion of time spent addressing issues with a longer time horizon.
Informing	• Policy, strategies and decisions adopting foresight findings, data and terminologies. • Setting a horizon scanning capacity.	• Reported use of foresight concepts and data. • Foresight findings regularly used as evidence-based policy- and decision-making. • Level of investment and use of horizon scanning.
Enabling	• Create effective links with foresight communities. • Improving capacity to deal with uncertainties.	• Level of recruitment of specialist foresight skills. • Number of foresight workshops and related events. • Size of budget allocated to foresight.
Influencing	• Reformulation of strategy in light of the learning from foresight. • Higher levels of innovation. • Structures to support future-oriented research. • Higher levels of confidence in planning and decision-making processes.	• Timeframe of defined indicators. • Extent of influence reported. • Number and scale of follow-on and spin-off foresight activities

In the context of foresight programmes, i.e. broader foresight initiatives on a national-scale, looking at a range of topics, Popper *et al.* (2010) suggest 15 lessons concerning key issues to be considered by sponsors and organisers of foresight activities. Thirteen of them are summarised in Table 9 below and can be informative in different contexts.

Two different post-exercise components should receive a special focus: evaluation of the effectiveness of the exercise and appraisal of turning foresight into an ongoing activity. While the latter might be seen as somewhat optional, the former is a pivotal part of the process. It ensures accountability, credibility and demonstrates the strengths of the foresight process. It is important to stress from the start that when evaluating foresight exercises, impacts also depend on external factors and cannot be controlled by the project. For instance, when foresight supports the development of a strategy, or makes policy recommendations, the uptake of such outputs is the sole decision of external actors and may depend on a good 'timing' (or a 'window of opportunity'). This per se does not mean that the foresight process was unsuccessful in its planning, development and follow up.

Table 9 Lessons from foresight programmes (adapted from Popper et al. *2010).*

Lesson	Description
Produce sharp messages	Findings and recommendations presented in a clear and concise manner.
Promote broad participation	Although large-scale participation sometimes is not ideal, incorporating a broad range of stakeholders and experts can provide several benefits to the Foresight process both on a knowledge base level and on greater legitimacy of the work and results and improved capabilities to use and take forward shared visions about possible or desirable futures.
Identify social science resources	Resources of social science can certainly contribute to the design and implementation of Foresight, even if its focus is technological or industrial.
Contextualise Foresight practices	As foresight exercises are always customised, the implementation environment needs to be considered at the design stage. Even similar studies done in the past might not be informative enough to designing the exercise.
Build shared visions	Regardless of the main objectives of the exercise, some planning for the future is vital for broader aspects such as identifying technological opportunities, potential problems, necessity for collaboration and complementary and competitive innovation, etc.
Remember interaction is vital	More than reports, publications and policy recommendations, it is vital to create and maintain networks and knowledge exchange processes (e.g. via workshops and seminars).
Avoid institutional memory loss	It is important to tap into pre-existing knowledge and experiences that are available internally (and externally). If there is previous Foresight experiences, this organisational learning should be leveraged.
Avoid potential diversions	Frequently in broader exercises (foresight programmes) a wide range of topics and actors are considered, which can be beneficial. However, it is important to make sure that the project does not deviate from its original objectives and expected results.
Avoid unavailable project/panel leaders	Such roles require people with sufficient time and dedication to coordinate frequent meetings.
Consider integrative elements	Possibly less relevant in activities for capacity building and training, some elements can be central in engaging, mobilising participants efforts (e.g. Delphi surveys).

Promote foresight absorptive capacity	Promote the ability to understand, incorporate and apply foresight concepts and practices – 'learning by doing'.
Beware of recognition challenges	An important task for Foresight is to pursue the creation of a Foresight culture.
Beware of foresight evaluation challenges	Evaluation practices still need improvement, it requires a more complex and contextualised framework.

5. Foresight Approaches, Methods & Tools Classifications

A range of formal tools and methods can be used in foresight approaches, which were reviewed in Deliverable 5.1 (Falck *et al.* 2017). Additional methods and tools were included in this assessment (Figure 14) and are described in the current report.

Qualitative

- Back-casting
- Brainstorming
- Citizens' panel or Focus Groups
- Expert Panels
- Futures Wheel
- Idea Networking
- Genius Forecasting
- Horizon Scanning
- Mindmapping
- Morphological Analysis
- Relevance Tree
- Scenario Art
- Scenario Development
- Serious Gaming
- SWOT Analysis
- Wild Cards and Weak Signals

Semi-quantitative

- Causal Layered Analysis
- Cross-Impact Analysis
- Delphi Survey
- DPSIR Frameworks
- Futures Triangle
- Roadmapping
- STEEP analysis
- Stakeholder analyses
- Structural Analysis
- Utility maximisation and choice modelling

Quantitative

- Bibliometrics
- Trend Extrapolation
- Trend impact analysis
- System dynamics modelling
- Global Value Chain (GVC) Analysis

Figure 14 Overview on foresight methods and tools scoped by the MICA project.

The ForLearn Portal[6] suggests distinguishing the different functions needed at different phases of the exercise:

- **Diagnosis:** understanding where we are;
- **Prognosis:** 'Foresighting' what could happen;
- **Prescription:** deciding what should be done.

Each of these functions might suggest a specific set of methods that can be more suitable. Diagnosis is frequently covered by Environmental Scanning approaches, identifying relevant trends and drivers of the system under study and structural analyses to better understand causal relationships. Prognosis might use Scenarios Development to explore what could happen or a mix of methods, balancing between qualitative and quantitative approaches. The prescription function can be covered with tools supporting the development of recommendations.

[6] Website: http://forlearn.jrc.ec.europa.eu/guide/4_methodology/meth_framework_functions.htm

When choosing methods for a specific exercise, it is important to understand key classificatory differences between the vast amounts of methods used in foresight exercises.
The foresight methods and tools are commonly classified:

- By their nature: Qualitative, quantitative or semi-quantitative;
- By their knowledge source: Interactive, creative, evidence, expertise-based; and
- By following either normative or exploratory approach.

The first aspect when looking at the various methods is the objective of the exercise previously defined. Framing the issue at stake with single questions can aid the translation of such issues into possible approaches. For instance, when asking "how will *something* develop in the future?" exploratory approaches tend to be more compatible with open-end questions, whereas asking "how can *something* become more sustainable?" introduces a more normative element. The principle of triangulation (see Chapter 6) suggests a combination of different methods and approaches to improve the robustness of the foresight methodological framework and increase its reliability.

Example
The European Foresight Monitoring Network (Popper *et al.* 2007)

The report mapped 755 foresight case studies (from different areas) and it was observed that the most frequent used methods are Literature Review (437), Expert Panels (397) and Scenarios (324). In some cases, for instance, Literature Review is not explicitly regarded as a method in the foresight process, which can mean its frequency might be even higher, since it is hard to imagine any project, study or report without some degree of literature review. Such mapping and monitoring approaches provide a good hint on which methods are easier to employ, be it for their (low) complexity in implementation, availability of expertise, not being so time-consuming and for being more exposed to scrutiny over time.

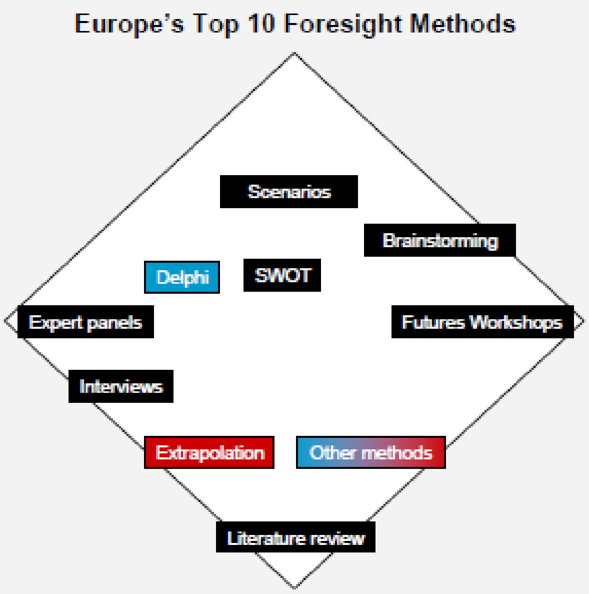

Figure 15 Europe's top 10 foresight methods (Popper et al. *2007).*

With relation to the time horizon of the projects, the usage of Delphi methods decreases when the time horizon becomes longer, while for scanning methods (e.g. STEEP – Social, Technological, Environmental, Economic, Political scanning) usage increases. SWOT (Strengths, Weaknesses, Opportunities and Threats) analyses and bibliometrics do not seem to be much used in studies looking far into the future.

Popper (2008) sought to capture the different foresight classifications with the 'Foresight Diamond' (Figure 16). It plots 33 methods in a diamond where each corner represents a knowledge source: Creativity, Expertise, Interaction and Evidence-based. The diamond also features a classification by the nature of the method: qualitative (bold), semi-quantitative and quantitative (italic).
The study defines as 'fundamental attributes' of foresight methods both, i. nature and ii. capabilities. By their nature they can be classified as:

- **Qualitative:** methods providing meaning to events and perceptions. Creativity or subjectivity play a significant role as the focus is on interpretations, judgements, opinions etc. Qualitative methods are often employed where the key trends or developments are hard to capture using simplified indicators. Various tools used in qualitative foresight approaches have a 'facilitating' background (for meetings and workshops), such as 'Mind Mapping'. In general, qualitative methods evolved into capturing and analysing quantitative data and displaying the analyses in a well-digested form.
- **Quantitative:** methods generally focus on variables, applying statistical analyses, using or generating reliable data. Quantitative methods rely on representing developments numerically. Numerical data are useful in thinking about future developments and can be useful to express Foresight results. A common property of quantitative methods in foresight is that they are variable-oriented. Advantages of using quantitative methods can be summarised as:
    - Works with a greater level of precision as it allows to compare data, examine rates of change, identify increase/decrease of relevant variables;
    - It can be used systematically to produce trend extrapolation/analysis;
    - Support the scale perspective of problems, underlining and validating comparisons with confidence for decision-making;
    - Results can be represented in charts, graphs and tables, which is often appealing in communication strategies.

  Disadvantages can be summarised as follows:
    - Some factors are hard to present numerically – and the more important they are the less likely quantitative approaches can be indicated. Avoid assuming that because something can be measured it is central to the exercise.
    - Skills required for working with quantitative data are unevenly developed. Apart from requiring considerable expertise to apply quantitative methods, it can be difficult to examine statistical information if they are in an upper level of complexity for general users/participants;
- **Semi-quantitative:** methods are basically applying mathematical principles to quantify qualitative subjectivity, judgements and opinions e.g. weighting opinions and probabilities.

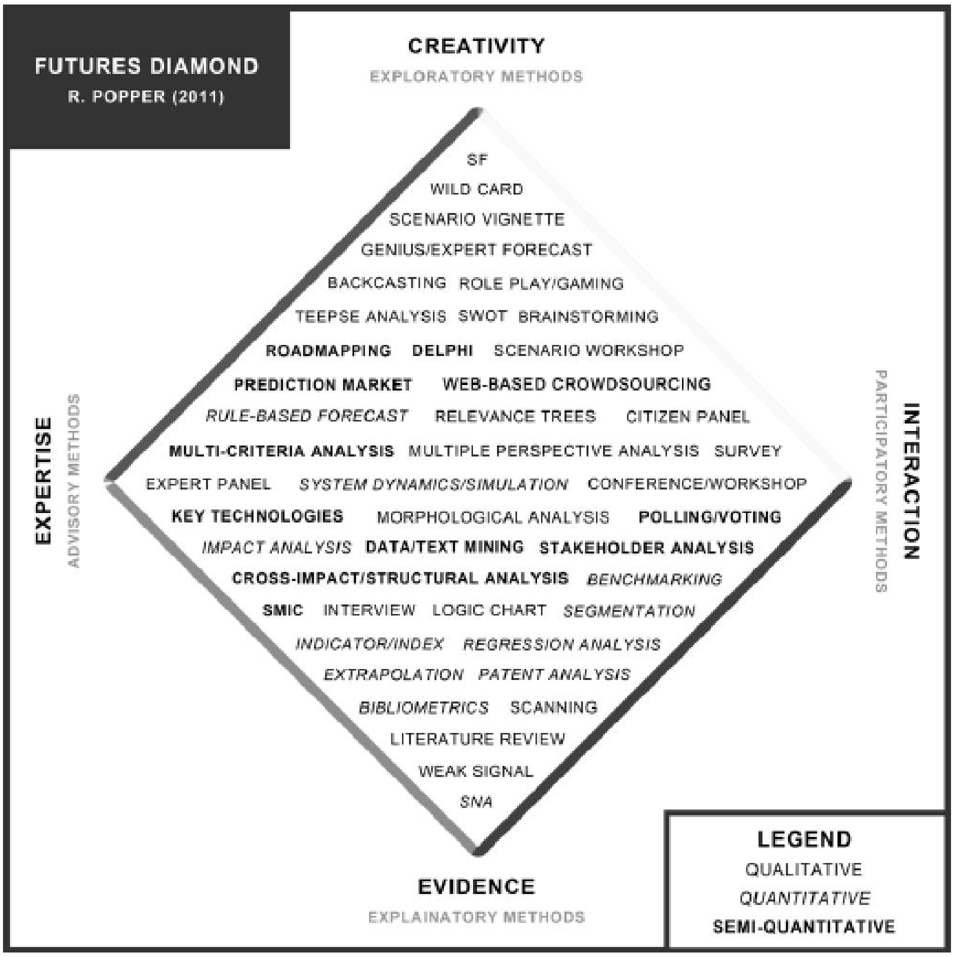

Figure 16 The Foresight Diamond (Popper 2011).

Qualitative approaches are becoming more and more important, while quantitative approaches are increasingly reserved to specific applications (Kreibich 2006). As foresight usually draws on both quantitative and qualitative approaches, quantitative data are often given a great deal of weight, but they should not be allowed to dominate. There is a high dependence on the access to expertise and nature of the problems being studied with finding the right mix of methods. However, mixing qualitative and quantitative methods underpins most of foresight studies as a rather desirable goal. The classification of 'semi-quantitative' methods underlines the demand for combining qualitative and quantitative techniques.

In terms of capabilities, foresight methods and tools can be described as

- **Creativity-based**: Methods rely heavily on the inventiveness and ingenuity of very skilled individuals.
- **Expertise-based**: Skill and knowledge of individuals in a particular area or subject is used to support top-down decisions, provide advice and make recommendations.

- **Interaction-based**: focus on the gains generated by expertise brought together, challenged with other stakeholder's perspectives. Especially important when the object of the study requires a more 'democratic' element in the process, with a more inclusive and participatory appeal.
- **Evidence-based**: providing the support for understanding the current state and possible developments.

Exploratory vs. Normative Approaches

As the European Foresight Platform defines, exploratory methods are 'outward bound'[7]. They begin in the present and move forward to the future, either extrapolating trends or causal dynamics, or else asking "what-if?" type of questions on the possible implications, developments and events that may lie ahead in the future. Trend (extrapolation) analyses, cross-impact analyses, Delphi surveys, some modelling techniques and scenarios can belong to the pool of methods used in an exploratory fashion.

Normative methods, by contrast, usually start from a point in the future with a view of a possible – often a desirable – future. They then work backwards to see how these futures might be reached from the present state, identifying constraints, resources and technologies enabling or disrupting the path to that desirable future state. Tools used in this case can be morphological analyses, relevance tree, aspirational scenarios and back-casting. Typically, studies with such approach would include the creation of a 'vision' through participatory workshops, integrating different – but converging – perspectives.

Most importantly, the practice shows us a mixture of both approaches. As sometimes an exploratory approach can serve as a starting point to identify a possible desirable approach or an undesirable one that should be avoided. Normative approaches are powerful in priority-setting studies, as well as creating the conditions for monitoring progress towards the desired future. Where consensus is hard to achieve and there is no clear vision of shared goals, explorative approaches are largely expected – at least as a starting point.

Kreibich (2006) identifies four different approaches to foresight, based on the different methodologies of futures research:

- Explorative empirical-analytical approach: Existing knowledge as well as new facts, data and trends are systematised under pre-defined assumptions and conditions analysed according to specific rules – it can be done in qualitative and quantitative form;
- Normative-intuitive approach: Experiences and facts acquired in a empirical-analytical fashion are explored creatively to provide a picture of the future e.g. projection of a desirable future;
- Planning approach: Knowledge and experiences are used creatively with the focus on shaping the future towards a desirable vision; and

[7] Source: www.foresight-platform.eu/community/forlearn/how-to-do-foresight/process/methodology/

- Communicative-participative approach: integration of different actors to increase possible future developments.

The different foresight methods usually fall into more than one of these different categories of approaches and only few of them actually fall into just one of the categories.

5.1 MICA – Operative tools vs. Planning tools

In the context of Strategic Raw Materials Intelligence, D5.1 (Falck *et al.* 2017) mapped the key functions differentiating between operative tools (e.g. descriptive statistics) and strategic, long-term planning tools (e.g. scenario development). Some methods and tools identified in Work Package 4 (van der Voet *et al.* 2016) can be combined with foresight methods for the analysis of longer timeframes. The publications mentioned in Table 10 were reviewed so as to set references to such complementary approaches.

Table 10 MICA Operative vs. Planning tools – References.

Publication	Description
Integration, Comparisons, and Frontier of Futures Research Methods (Gordon & Glenn 2004)	*Econometrics* and *Statistical Modelling* can relate quantitative or exploratory approaches in a foresight context. Together with e.g. Futures Wheels it can help establishing relationships for estimating the consequences of decisions. Scenarios can then be used to define assumptions on which the analysis is based. In general, scenarios can provide the backdrop for econometric analyses and help to ensure the internal self-consistency of external assumptions. The authors also suggest that a Cross-Impact Matrix of future events can be introduced into an econometric analysis and through simulation methods (e.g. Monte Carlo Simulations[8]) a new random selection of independent variables could be found.
Framework for Scenario Development in LCA (Pesonen *et al.* 2000)	The authors suggest that Scenarios can be applied to *Life Cycle Assessments (LCA)* by describing a possible future situation relevant for specific *LCA* applications. Backcasting could also be used to present the development from the present to the future. It suggests three different types of Scenario applications: technology scenarios, environmental scenarios and valuation scenarios. Although time spans referred in LCA studies using scenarios are frequently smaller than in foresight scoping, the 'Cornerstone' scenario approach is more applicable to longer timeframes as it is less quantitatively oriented. Different alternatives (cornerstones) are developed to give a better view of the field and can serve as basis for further, specific, research. It is considered to be more appropriate in public policy-making context.

[8] It can be used with virtually any modelling technique to convert a deterministic, single-value solution into a probabilistic solution.

6. Foresight Methodology Frameworks

The methodological framework of a foresight exercise relates to the definition of which methods – and in which sequence – it will be used according to the various factors controlling the foresight process (e.g. context, resources etc.). We can distinguish the methodological framework and the actual methods that populate it. The framework is a sequence of methods that, combined, generate the information at different stages of the process. For instance, quantitative methods can be more intuitively considered for generating relevant empirical data, whereas qualitative methods can define the framework in which these generated data will be assessed. However, the available expertise might be reliable enough to do away with the actual use of such quantitative approaches within the foresight exercise, assuming that the experts are aware of data and facts.

A methodological framework is what differentiates foresight from a mere reflection on futures. Defining the appropriate sequence of methods to be used is critical to a successful foresight process – as even the same methods used in a different order may tackle different objectives and produce different outcomes. It is important to recall that this is also an evolutionary process, an ongoing adaptation as the foresight process develops.

Often, the triangulation principle can be used to support the definition of a methodological framework in qualitative and quantitative foresight approaches. The term can be traced back to navigational and land surveying techniques that determine a single point by measurements taken from two other known points. As a research strategy and in futures studies it can reduce biases or deficiencies of using only one method (Rothbauer 2008). It draws on the idea of having multiple methods, perspectives and sources of data, combining qualitative and quantitative methods to improve the reliability of the foresight study (Kaivo-oja 2014).

In the context of foresight, this can be extended to other forms of classification, thus a 'triangulation approach' can bring together evidence, expertise, creative and interaction-based methods. It is also to be noted that the way in which these methods are combined is important – that is to say, the same set of methods can be combined differently to produce different outputs; see Figure 17.

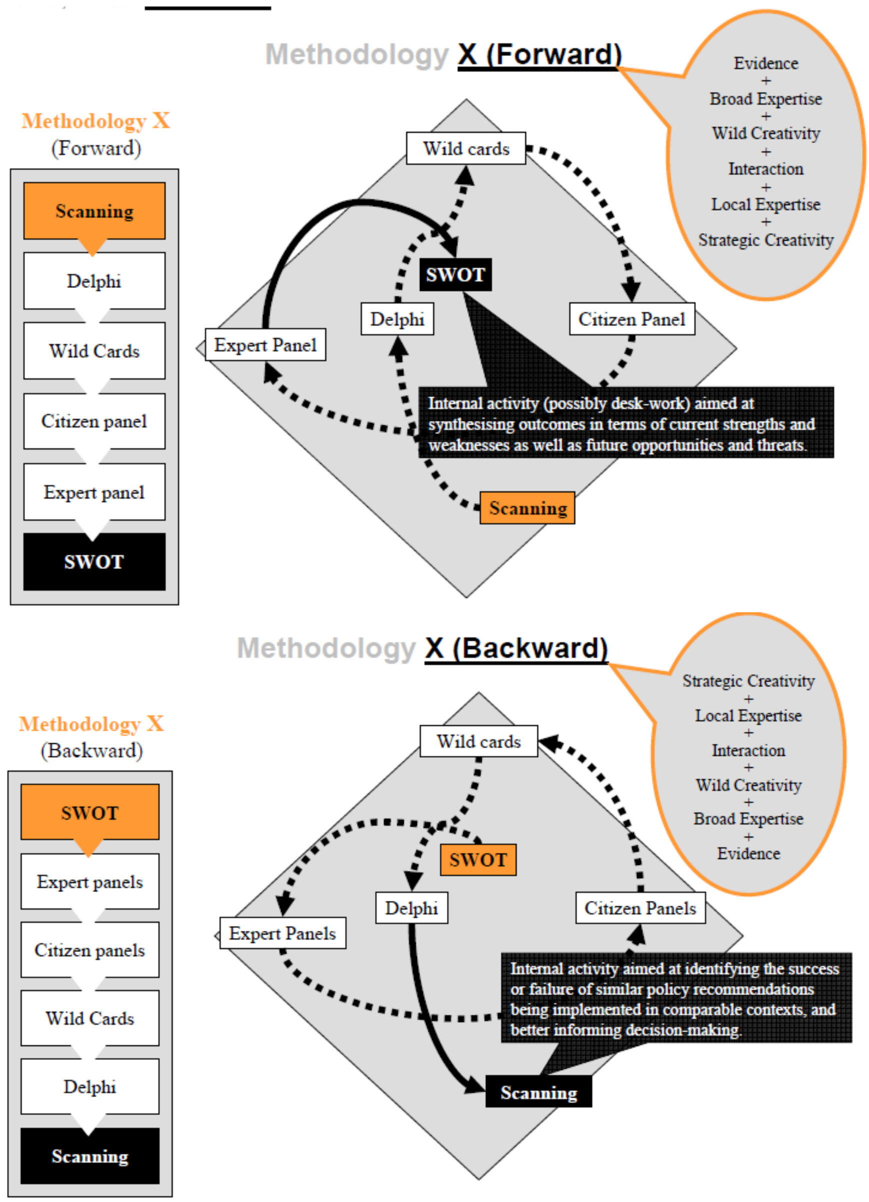

Figure 17 Foresight methods combinations (Popper 2008).

Example
Recreate Project – funded by the European Commission (Grant Agreement no. 603860)

The overall objective of the project is to support the development of the European Union's new research funding programme Horizon 2020 with a specific focus on "Societal Challenge 5: Climate Action, Resource Efficiency and Raw Materials", by providing an evidence base. Its main objectives can be summarised as:

1. Assessing the impact of potential break-through innovations in relevant fields;
2. Developing Scenarios and analysing trends that help to define research and innovation priorities;
3. Benchmarking Member States' performance in the relevant fields;
4. Creating and maintaining a broad network of stakeholders that get involved in the above activities; and
5. Transmitting the knowledge produced by the project effectively to policy-makers and other target groups.

A dedicated work package on forward-looking analysis aims at delivering knowledge on the risks and possibilities in the development of the three focus areas. It monitors trends and delivers policy recommendations for designing R&D support programmes and other instruments within the EU. It also includes the development of a plausible future vision of EU in the year 2050, where policies created to reinforce the synergies between the three focus areas have induced European innovation, increased well-being, and created new jobs. Foresight workshops seek to provide an arena for strategic decision making and priority setting. Figure 18 features the foresight methods used in the project and Figure 19 illustrates the process of scenario development.

Figure 18 Foresight methodology framework – Recreate Project (adapted from Dufva et al. *2015).*

As drawn in the report "Three integrated scenarios until year 2050 – no. 1" Dufva *et al.* (2015) describe the methodology framework as:
Literature Review collecting evidence of the three RECREATE areas (Climate Action, Resource Efficiency and Raw Materials); a scoreboard document establishing key indicators of the related areas and policies, monitoring changes and impacts; a stocktaking analysis consisting in a related policy analysis of selected European and non-European countries; Trend Analysis is used to identify current and foreseeable trends having impact on the three areas in scope. Interactive and creative approaches are carried out to represent different disciplines and stakeholder communities together with (expert) interviews of policy makers. These elements together form the knowledge pool (factor analysis) of the Foresight study. This knowledge pool creates the basis for developing and iterating the process of Scenario building.

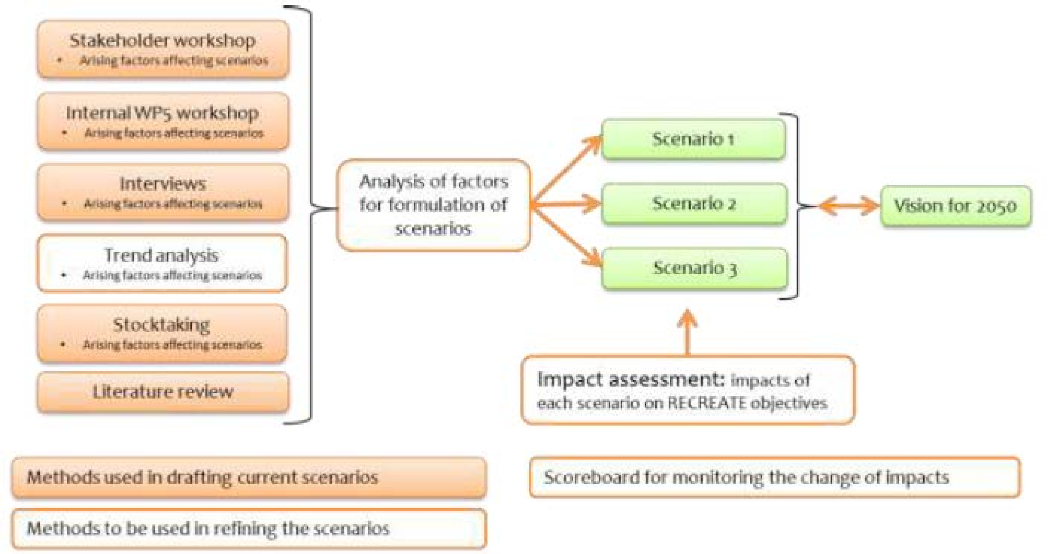

Figure 19 Formulation of the three RECREATE scenarios and state-of-the-art in the use of elements affecting the scenario building (Dufva et al. *2015).*

6.1 'Layers of Depth'

Generic foresight frameworks have been published as guides for practitioners to be incorporated and to facilitate their approaches to designing foresight exercises and selecting foresight methods. Voros (2005) proposed the concept of 'Layers of Depth', attempting to integrate several different 'depth' typologies and methods into a single approach – the Generalised Layered Methodology (GLM). The practitioner could then move to deeper levels of understanding progressively and also use it as a template to adapt frameworks, as needed, in the foresight process.

Voros (2003) classified foresight methodologies into four levels (Figure 20):

- **Input:** what is going on?
- **Analytical:** what seems to be happening?
- **Interpretive:** what is really happening?
- **Prospective:** what might happen?

Input methods gather information needed to understand the (contextual) environment (Conway 2008). The Delphi survey is a classic example of an input method.

Analytical methods are also used to obtain information during the input stage. Typical examples of such methods are Trend Analyses. Trends are flows of transformation that are not easy to be changed (Kuosa 2014). They can be the expression of a historic path or pushed by marketing or self-fulfilling prophecies and tend to follow a predictable trajectory. They are useful in identifying emerging issues, especially when they are at the periphery of mainstream trends (Conway 2008); see Figure 21.

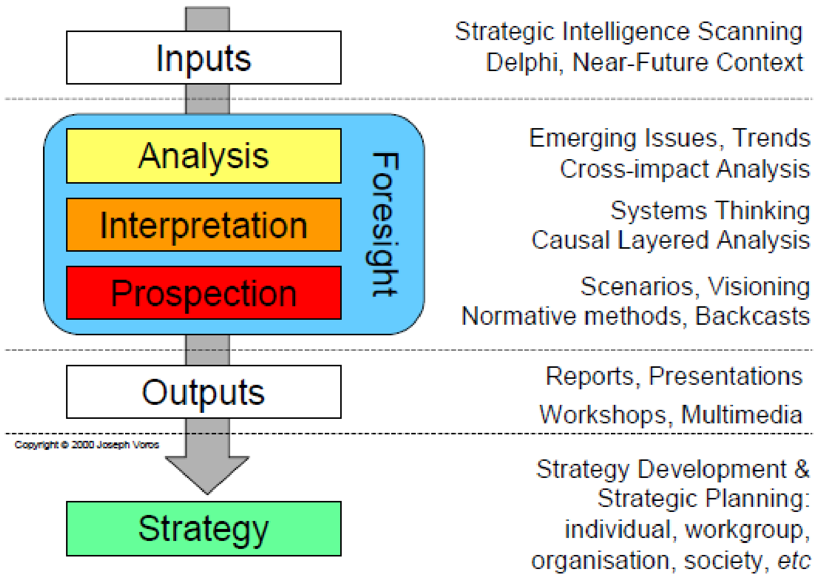

Figure 20 Generic foresight process and related methods & tools (Voros 2003).

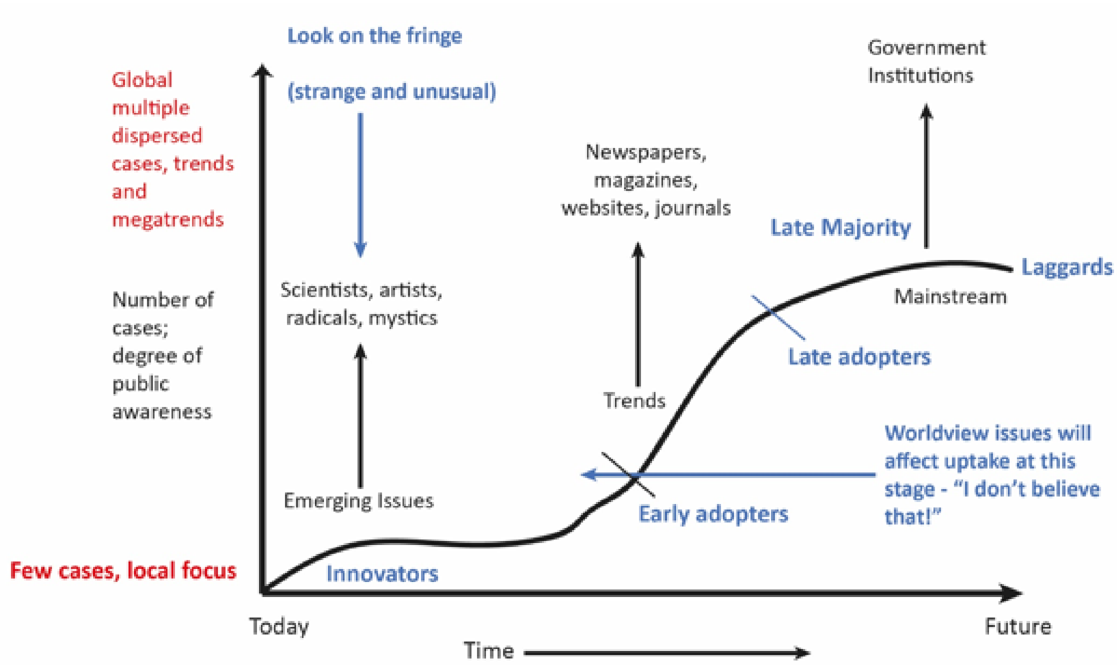

Figure 21 Trend Cycle (adapted from Conway 2008).

Other analytical methods include cross-impact and morphological analysis.

Interpretive methods aim at making sense of the information that has been collected and categorised in previous steps. Methods such as Causal Layered Analysis emerge with the concept of 'layers of depth' as a sophisticated approach to move beyond categorisation of data.

Prospective methods look at what might happen with a more explorative view of alternative futures. Scenario planning is a classical method in that sense. Scenarios, if done well, can offer an integration of external environmental factors, both qualitative and quantitative, with information about the internal environment. In a more normative fashion, back-casting methods relate to a preferred future that should be attained.

The actual methods employed at each stage are not fixed – they remain open by the foresight practitioner, subject to specific requirements of the foresight engagement (Voros 2005). The diagram in Figure 20 appears to indicate a linear process. However, the author underlines both conceptual and practical feedback loops from later phases to earlier ones.

Inayatullah (2008) proposes the Six Pillars approach for foresight rooted in six basic futures concepts (see also Table 11):

- **The used future:** relates to the self-understanding of the future image – is it a desired future, or a future vision borrowed from someone else?
- **The disowned future:** the act of creating a particular direction might ignore other possible developments.
- **Alternative futures:** is about acknowledging the alternatives. As the author claims, many people remain in a state of 'future shock' e.g. those living under socialist regimes in eastern Europe after the demise of the Soviet bloc had nowhere to look, not knowing what to do.
- **Alignment:** the need to align day-to-day problem-based approaches to strategy, strategy to broader and bigger pictures, the bigger picture to visions and then align back visions to day-to-day lives.
- **Models of social change:** range of understanding oneself role against the future by asking – is the future positive and can one do something about it? Or is the future bleak and there is nothing one can do about it? Or is the future already given or created?
- **End uses of the future:** about what can be done with futures thinking, as it can be just about foresight training, helping individuals and organizations with new competencies and skills, help to create more effective strategy, become more innovative, creating capacity. Is about enhancing the confidence to create futures that we desire.

Prior to that, Slaughter (1997) suggested methodological groups to the strategic Foresight process so as to broaden the boundaries of perception. Table 12 sums up the suggested methodologies and methods.

Table 11 Six pillars of future studies (adapted from Inayatullah 2008).

Pillar	Description	Typical methods and tools
Mapping	It maps the past, present and future. Through workshops, it induces to a 'shared history'	Futures Triangle
Anticipation	Identification of emerging issues (disrupters), develop the consequences of current issues into the long-term future	Futures Wheel
Timing the future	Search for grand patterns of history and identification of models of change	-
Deepening the future	Unpacking the levels depth of the future. It dives into the commonly accepted future, causes of the issues, the general culture or worldview and the deep unconscious story behind it.	Causal layered Analysis
Creating alternatives	Analysing different way of doing what is currently practiced, and creating alternative futures	Structural analysis, Scenarios development
Transforming the future	As possible futures were explored, this pillar narrows it towards a preferred one.	Backcasting

Table 12 Methodological groups to strategic foresight (Slaughter 1997).

Methodological groups	Description	Related Foresight methods
Input methods	Gathering relevant material, highlight emerging issues. Selecting key questions to research is an important determinant of the outcome.	Delphi
		Environmental Scanning
Analytic methods	Tend to be not so much free-standing methods in their own right so much as stages in a larger piece of work. For instance, Cross-impact would be typically used to analyse a series of pre-identified factors in order to understand interrelationship, which in turn will support a later scenario building process.	Cross-impact
		Forecasting and trend analysis
		Backcasting
Paradigmatic methods	Phenomena can be understood in various ways. Usually, one finds empirical descriptions in a somewhat superficial assessment of the issues at stake. A deeper look can uncover a lot about the way these issues are handled socially through e.g. regulatory regimes and governance.	Causal layered analysis
		Systems thinking
Iterative and exploratory methods	They permit a substantive definition or exploration of future states, options or strategies	Scenarios
		Visioning

6.2 'La Prospective'

During the 1970s in France, the French Atomic Commission (CEA) proposed a methodology related to the assessment of future developments for the nuclear energy sector. Such approach merged qualitative judgement with quantitative methods in order to assess explicit and hidden relationships between variables (drivers) of a system under analysis (Keenan *et al.* 2003). This particular school differs from 'standard' strategic foresight mainly on factors related to a more pro-active attitude, the scenario building process and the focus on involving and engaging the client (user). Figure 22 summarises the process and methods of 'La Prospective'.

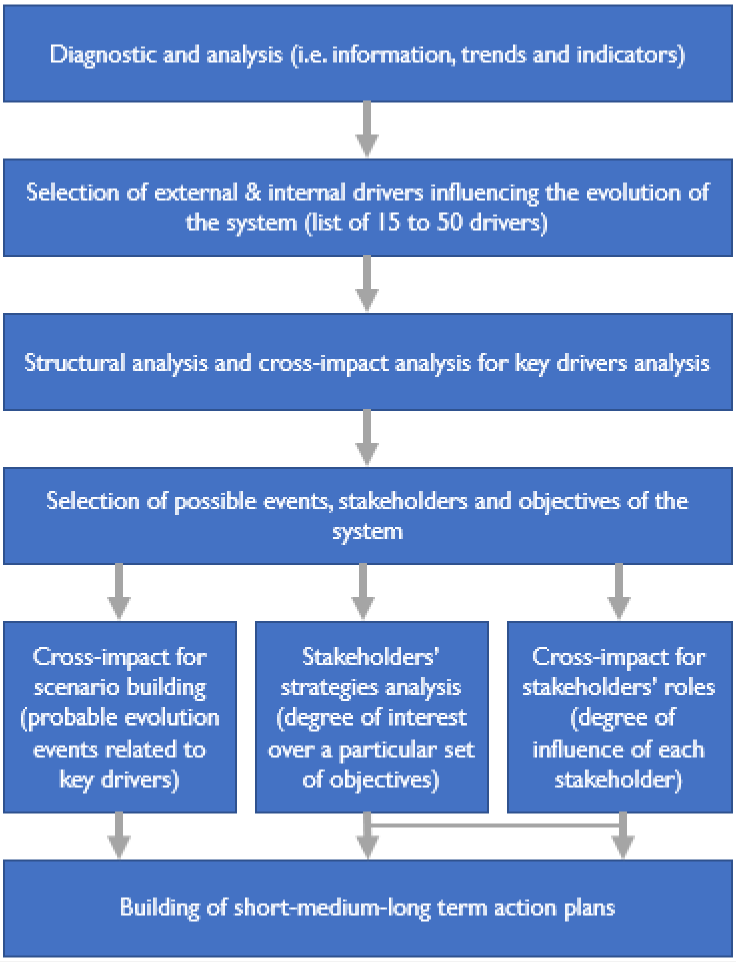

Figure 22 'La Prospective' Process and Methods (adapted from Keenan et al. *2003).*

6.3 A Point in Case – Scenario Approaches

From the review of past Raw Materials Foresight Case Studies (Appendix A, page 95) it was observed that Scenarios were frequently applied tackling different issues and contexts, with substantial variations in their application (Martins & Bodo 2017). Figure 23 provides an overview over the frequency with which each method was observed in the 'Raw Materials Foresight Case Studies Inventory'.

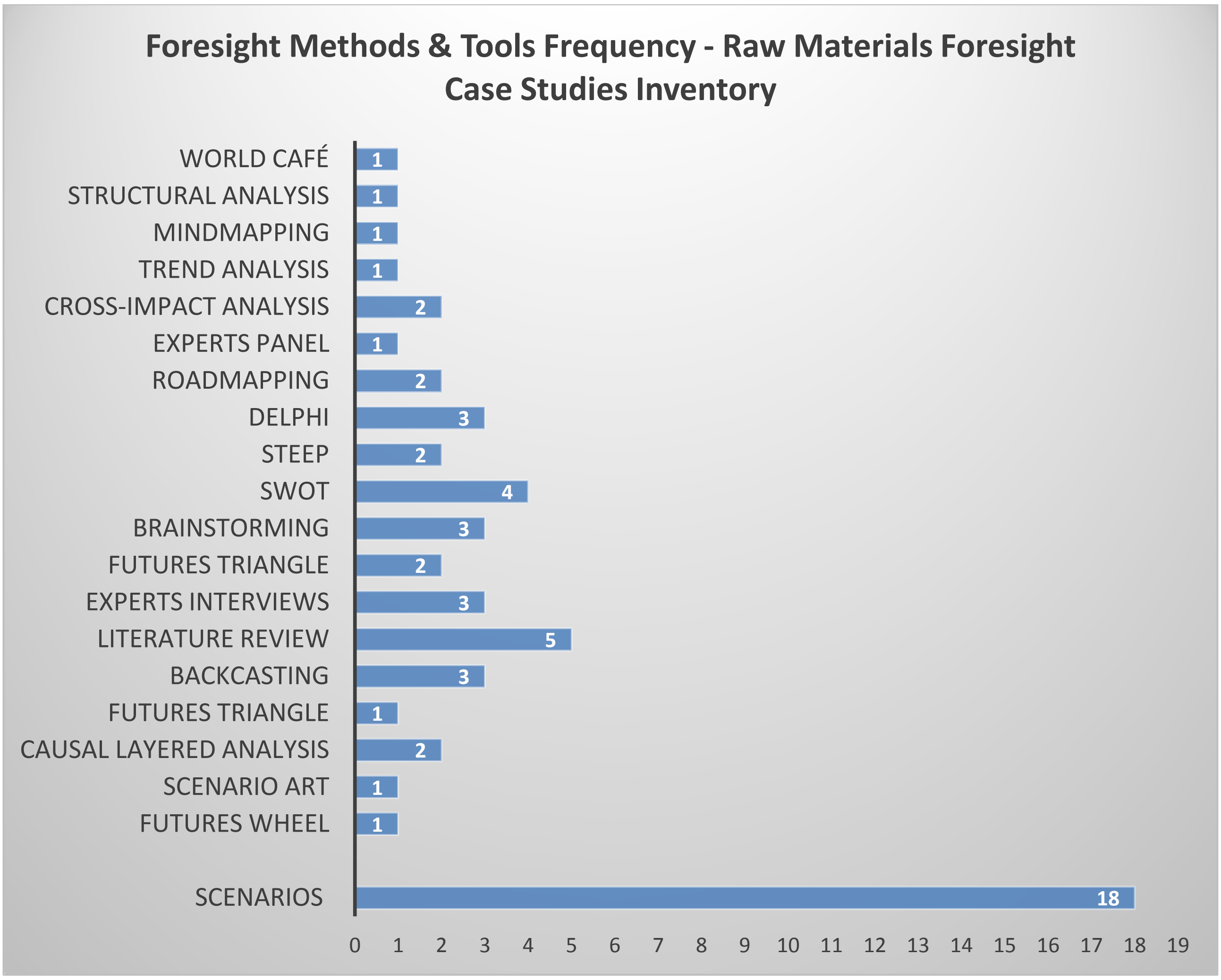

Figure 23 Foresight Methods & Tools – Raw Materials Foresight Case Studies Inventory.

It can be noted that Scenarios are by far the most frequently used method in foresight studies related to raw materials. However, it is important to distinguish between the different approaches and the Scenario's methodology. This section will provide an overview over the different options when applying scenario analysis to a foresight study.

The emergence of scenario analyses can be traced back in time similarly to foresight development, described in Chapter 2. In essence, Scenarios are not about knowing the future, but rather preparing for it (Sarpong 2011). It is perceived as a logical and formal construction of an alternative vision of the future. It involves a heterogeneous group of experts and assesses important relationships between relevant factors of an examined phenomenon. Ultimately, it enables decision-making about the future (Nazarko & Kononiuk 2013).

Although frequently treated as just a method, Scenarios can be developed using numerous different approaches. Kosow & Gassner (2008) suggest that rather than being a method, scenario analyses can be referred to as methods, due to the vast number of possible approaches, techniques, research and workshop designs. Furthermore, Scenarios can fall into virtually all main foresight methods classifications, acting either as a normative or exploratory approach with quantitative or qualitative properties, and as an inductive (bottom-up) or deductive method (top-down). It, thus, presents an interesting case for analysing methodological approaches in foresight against a backdrop of more qualitative, longer term, raw materials contexts.

This section provides an overview over the Scenario analysis methodology, its implications for foresight methodology frameworks and its applications to raw materials.

According to Kosow & Gassner (2008), this multiplicity of different Scenario approaches can be explained by five factors:

- It evolved into different techniques together with the development of different applications for Scenarios;
- The spectrum of goals and functions widened considerably since the first emergence of the Scenario concept;
- Different schools of thought and paradigms have influenced the work on Scenarios by embedding different perspectives and patterns of thought into the field;
- It has a variety of positions of importance in a project or research process – it may be an end product, but also a point of departure (Scenario evaluation/exploration) or even an intermediary component – 'a step in the process'.
- Finally, different labels might exist for similar approaches just to give more prominence to a service provider's own approach.

Therefore, when referring to Scenarios, various approaches are actually being contemplated and it is important to be able to make such distinction.

Kosow & Gassner (2008) suggest a common derivation of five different phases of Scenario building; regardless of the approach. They can be summarised as:

- **Identification of the Scenario field:** outlining the purposes of developing Scenarios – topics contemplated and boundaries are also object of definition.
- **Identification of key factors:** Central points that together can form a description of the Scenario field – they are variables, parameters, trends, developments and events to receive special attention during the Scenarios development process. Identifying such key factors requires knowledge of the Scenario field of interactions between the various key factors. The actual process of identifying these factors varies according to the Scenario approach being applied.
- **Analysis of key factors:** This analysis enables the widening of thinking around these key factors, which is an important feature of Scenario approaches. It tends to involve more intuitive and creative aspects. It is a critical step for a coherent visualisation of the various future developments.

- **Scenario generation:** Consistent factors are brought together and worked up into Scenarios. In this phase, the actual generation also depends on the Scenario approach being applied – it can range from narrative procedures to formalized mathematical techniques.
- **Scenario transfer:** This phase supports the application or processing of the Scenarios that have been generated to a useful format for the project/exercise according to the previous purposes and objectives.

Kosow & Gassner (2008) suggest two different scenario techniques: trend-based and key factor-based (see Figure 24). These can be more detailed as follows:

- Scenarios on the basis of trend extrapolation: where the Scenarios are supported mainly or exclusively by trend projections. The framework will typically include the combination of Trend Impact Analysis (TIA) and/or Trend Extrapolation/Trend Analysis. The latter, however, typically falls under a single 'forecast' as it only singles out one Scenario – only a single development comes under observation. It can also be used as a reference Scenario serving for comparison with other Scenarios, which can be more qualitatively developed. Trend Impact Analysis, however, might compensate the weakness of extrapolation by analysing the influence of future events on the development of trends, through e.g. Experts survey. Therefore, TIA can display a spectrum of possible future developments for individual factors.
- Key factor-based approaches:
  - Systematic-formalised scenario techniques: the basic concept behind this approach is to start from a definition of key factors, and vary and combine them to generate different scenarios. This systematic approach is supported by tools such as Structural Analysis or Cross-Impact Analysis. The Scenario descriptions are usually cast into the form of a text, accounting for the corresponding future situation and the paths leading to it. These techniques in essence feature subjective and intuitive aspects in both, defining the characteristics of key factors and selection of the Scenarios.
  - Creative-narrative scenario techniques: they are mainly characterised by the explicit implementation of creative techniques, intuition and implicit knowledge elucidation. They frequently have a very strong participatory and outreach component. A typical example of this approach is the definition of two key factors, having each a certain degree of uncertainty and impact, resulting in two axes (2x2 Scenarios). More complex creative-narrative techniques can include:
    - Intuitive Logics: Focus on decision-making processes accounting for unpredictability and gathering of general information about the future. It is important to stress that the 'intuition' aspect is actually covered by experts, persons who are actively involved in the related processes and most familiar with the field. Typical tools supporting the process are STEEP (identifying and categorizing key factors) and SWOT analyses for converting the Scenarios into strategies;
    - Morphologic Analysis: in essence, it explores possible futures by assessing combinations resulting from breaking down a system under analysis in its

components. Morphological Analysis is used for studying complex networks of non-quantifiable relationships. This serves as basis for the development of Scenarios. The components of the system are analogous to the earlier mentioned 'key factors' and such components are thus studied – preferably in a context of a workshop, with wide participation of stakeholders – to understand possible future developments. Once the assessment of the self-consistency of combinations of the components is done, a clustering of the components (key factors) characteristics can be used to create the Scenarios.

- Normative-narrative Scenarios: the normative component allows for creating conceivable and desired futures descriptions, establishing a broader base for discussion of options and actions to reach a desirable perspective. The narrative component refers to the shape of the scenario outlook as in a quasi-literary style. Contextualising the issues helps to put the Scenarios into the related perspectives.

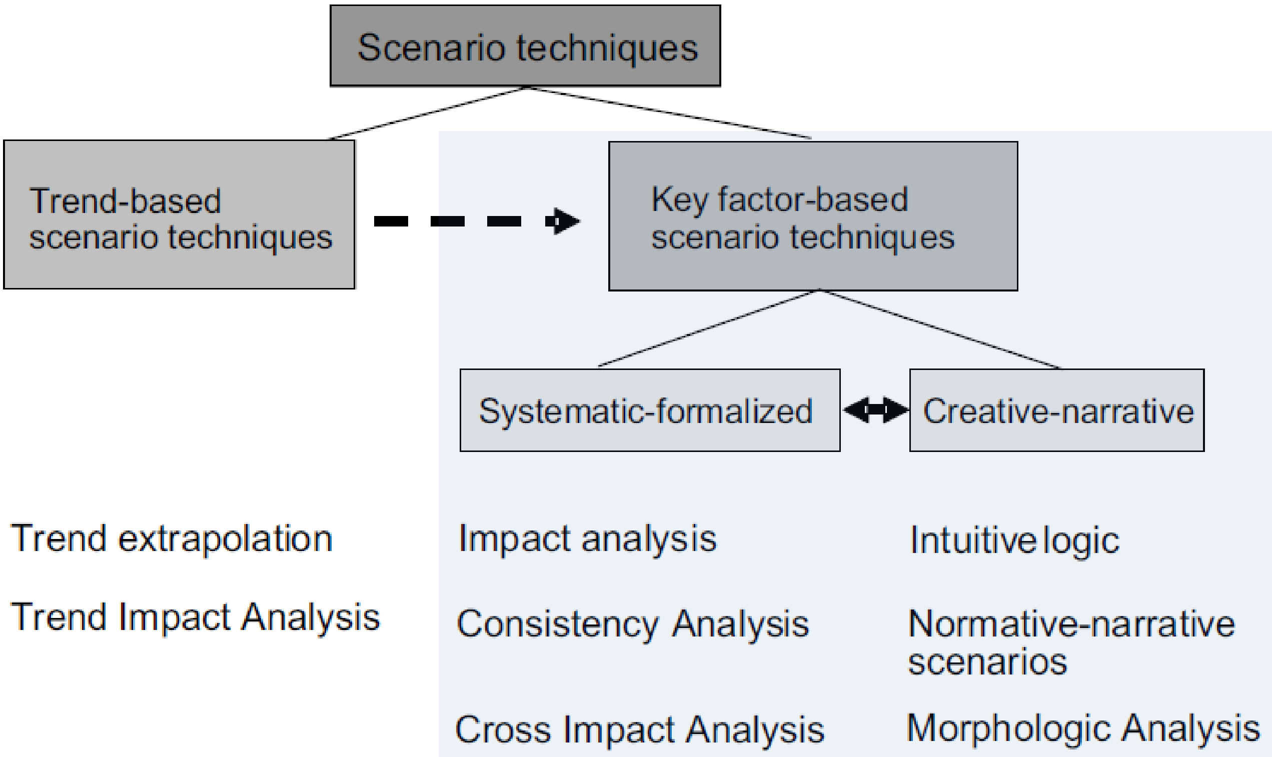

Figure 24 Scenario techniques (Kosow & Gassner 2008).

Foresight approaches under the Strategic Raw Materials Intelligence concept are understood to focus on more qualitative/longer-term futures. This can be translated into a higher appeal for key factor-based Scenario techniques (Figure 24).

Kuosa (2014) identifies typical story-lines presented together with the Scenarios, which can emerge regardless of the methodological approach used. Table 13 adapts this to a raw materials context.

Table 13 Typical scenarios storylines (Adapted from Kuosa 2014).

Storyline appeal	Raw Materials Example
Everything is fantastic	Free Trade / Sustainable approaches as norm.
Everything goes badly	Protectionist practices dominate, restrained raw materials supply.
Everything goes on as usual	Cyclical behaviour of mineral commodities with eventual supply disruptions for specific raw materials.
One thing works well, but another works badly	Access to supply is reasonable, though sector lacks sustainable practices and decisive actions to it.
Everything starts badly at first, but then will see better days	Supply concentration/monopoly gives space for more spread sources of specific raw material (or substitution enters the scene).
Everything goes well at first, but then turns out badly	Reasonably available raw material becomes increasingly controlled by a specific nation or economic bloc with antagonistic ideologies or diplomatic relations.
There is a game change x because of a trigger incident	Breakthrough technologies uncover and make available previously undiscovered resources in massive quantity.

In participatory approaches, the utilisation of scenarios can be subject to some draw backs e.g. general hardship from stakeholders stemming from the difficulty of trying to engage with the scenario building process and visualisation. Some alternative approaches can be adopted to facilitate or even simplify the utilisation of scenarios, when the circumstances seem suitable. This report suggests two approaches for circumstances where engaging stakeholders seem to become too difficult or when time constraints seem to indicate faster approaches for applying scenarios.

Pre-defined scenario backdrops

Inayatullah (2008) evokes two approaches in this sense: scenario archetypes (Table 14) and organisational-focused (

Table 15).

Table 14 Dator method – scenario archetypes.

Scenarios	Continued Growth	Collapse	Steady state	Transformation
Description	Current conditions are enhanced.	Continued growth fails. Greater contradictions	Seeks to arrest growth and find a balance in the economy and with nature. Human values are first	Seeks to change basic assumption of the other three scenarios: dramatic technological or human consciousness changes.

Table 15 Schwartz method – organisational-focused.

Scenarios	Best Case	Worst Case	Outlier	Business as usual
Description	Inserts a normative factor, as a future image to move towards (a desired state)	Where everything goes bad	A disruptive future where an emerging issue reshapes the future landscape	No important changes, extrapolation of the status quo.

Scenarios exploration

As the process of building scenarios can require a reasonable amount of resources such as time and interactive meetings, an option to facilitate the process of tapping into the benefits of exploring alternative futures is to use existing scenarios that somehow align with the context of the study being carried out. One example was set by the Mineral Futures Collaboration Cluster[9]. In such case, the study also utilised Scenario Art[10] as a tool to improve creative thinking with stakeholders and workshop participants regarding the scenarios.

More recently, the INTRAW Project (see Table 16) produced future scenarios with the backdrop for advancing international cooperation mechanisms on mineral raw materials through a key-factor based scenario development approach[11]. This can be suggested as another source for scenario exploration in the mineral raw materials foresight context.

[9] See Prior *et al.* (2013) for more information
[10] See Mason *et al.* (2011) for more information
[11] See Martins & Bodo (2017b) for more information

7. Raw Materials Foresight Case Studies

7.1 Overview

Deliverable 5.3 (Martins & Bodo 2017) presented a first version of the 'raw materials foresight case studies inventory', consisting of numerous past case studies that applied foresight methods and tools in a raw materials context. This inventory was subsequently upgraded and is featured in Table 16, with a description of main objectives, context and methods and tools utilised. From this review, six thematic clusters were deducted:

- Geographic orientation (e.g. 'National Benefit');
- Paradigm shifts (e.g. sustainability-related);
- Research/Technology;
- Stakeholder engagement;
- Supply/demand challenges;
- Policy support.

These will be described in more detail in Chapter 8. The case studies were built generally over multiple sub-topics from each thematic cluster. Figure 25 provides an overview over the frequency of the thematic groups observed in the inventory.

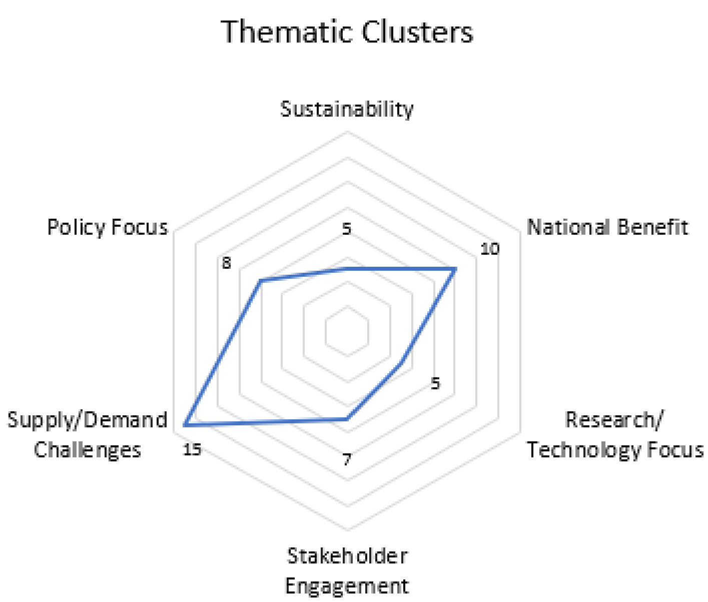

Figure 25 Raw Materials foresight thematic clusters.

Table 16 Raw Materials Foresight Case Studies Inventory – Upgraded.

Title	Country/ Authors	Year	Main Goals	Context/Background	Methods/Tools
Mineral Futures Collaboration Cluster	***CSIRO + 5 Australian Universities***	***2009-2013***	*Foresight into long-term strategic challenges, future scenarios, social, economic and regional contexts - transforming Australian minerals landscape with technology & innovation. Particular focus on impacts of remote operations and automation technology on indigenous employment in the minerals industry*	*3-year project to tackle the sustainability of the Australian mining industry in the context of the last mining boom: declining ore grades, shifting operating environments, globalisation, climate change, evolving community expectations. Divided into Commodity (How might global supply, demand and consumption patterns change?), Regional (How will future mining investments affect social and economic capital through transitory land use change?) and Technology (What technology is required and what will be its impacts?) streams of research. Foresight - what might alternative futures look like in terms of main drivers for investments & key issues and concerns for society. Framing issues: peak minerals timelines and lifecycle implications? what is a total cost of a mining operation? Effective planning for future regional development.*	***Material Flow Analysis (WP4). Megatrends and Scenarios (Exploration), Futures Wheel, Scenario Art, Causal Layered Analysis, Futures Triangle, Backcasting, Literature Review.***
Mining & Metals in a Sustainable World 2050	***World Economic Forum / BCG***	***2015***	*Framework supporting major transitions shaping the industry value chain, adjusting critical questions to a more sustainable world.*	*Financial Crisis / More sustainable operations / SD Goals Agenda (UN) / Uncertainties*	***Scenarios Development***

Foresight as a tool for sustainable development in natural resources: the case of mineral extraction in Afghanistan	***Pakistan / Sheraz, U.***	***2014***	*Realize the mineral potential efficiently, equitably and use it as means of effective socio-economic development and prosperity.*	*Recent mineral wealth discovered / China as an ally / Production in the vicinities of consumption / Resource curse risk*	***Causal Layered Analysis, Scenario Development***
Mining & Metals Scenarios to 2030	***World Economic Forum / McKinsey***	***2009***	*Stimulate dialogue / Provide multidisciplinary perspective insights / context for stakeholders to share their perspectives / Provide tools for decision making and collaborative actions.*	*Financial Crisis / Ever-increasing Globalization / Environmental & Climate Challenges*	***Scenarios Development / Brainstorming***
Alternative Scenarios for the North American Mining & Minerals Industry	***US / MMSD Scenarios Work Group IISD***	***2001***	*Assess global mining & minerals in terms of transition to sustainable development / Identify how and if the services provided can be delivered in accordance with sustainable development / Propose key elements for an action plan / Build a platform of analysis and engagement for ongoing cooperation and networking between stakeholders.*	*Disconnection between practices and values of today's society leading to concerns over the Social License to Operate*	***Scenarios Development, Back-casting, Brainstorming***
Foresight Mining & Metallurgy Report	***South Africa /NRTF-DACST***	***2000***	*Improve wealth creation and quality of life, to identify key topics and strategies the Mining & Metallurgy sector over the next 10 to 20 years.*	*National Research & Technology Foresight launched program seeking to identify key areas and market opportunities*	***Scenarios Development, Trend Analysis, SWOT analysis, STEEP scanning, Delphi***
Global Foresight and Roadmapping for the development of the Rare Earths Industry in Brazil	***Brazil / PUC Rio***	***2014***	*To structure a long and medium-term agenda, linked with the development of Rare Earth Elements productive application chains.*	*Chinese Monopoly / Chinese Exports Quota Restrictions / Higher Prices / Increasing Demand / Limited Supply*	***Scenario Development, Roadmapping, Brainstorming, Expert Interviews***

Polinares - Future World Images and Energy and Mineral Markets	***EU / Clingendael***	***2012***	*Identify the main global challenges relating to competition for access to resources, and to propose new approaches to collaborative solutions - Reconnaissance of the future of geopolitical and geo-economic relations and the impact on energy and mineral market policies.*	*World on the verge of a transition period, in which the share in international production, trade and finance of emerging markets is growing fast. Larger weight of the emerging economies in world GDP. Geopolitical impact of these countries is increasing, not only as a result of their growing soft power but because of their increasing hard power. OECD countries are meanwhile experiencing a relative decline in terms of economic importance and geopolitical impact.*	***Scenario Development***
Using scenario planning to improve the integration of geological, technical, economic, environmental and socio-political factors in minerals exploration management and strategy.	***Australia / Sykes, J.***	***2016***	*How the methodology can begin defining some parameters for the 'undiscovered accessible reserves' - considering the complex interaction of geological, socio-political, environmental, technological and other factors. To compare each scenario with the 20 main copper projects to determine which deposits are the best proxies to guide exploration targeting.*	*Consensus over the declining copper ore quality, with resource depletion paradigms determining views of long term future. Increasing on general costs can be mitigated with new discoveries. Struggle in scientific and economic techniques to incorporate the multiple external factors affecting the copper mining in the future.*	***Scenario Development, SWOT***
Minerals 4EU - Developments on the Raw Materials Market	***Minerals4EU / BGR***	***2015***	*Explore how technological change influences the demand for raw materials and illustrate how this can be taken into account when generating forward-looking raw materials intelligence, including scenarios for future demand. A particular focus is placed on so-called "technology metals"*	*Influence of technological change and substitution on the demand for the non-energy raw materials*	***Scenario Exploration (Over Polinares')***

Recreate Project	***VTT***	***2013-2018 (ongoing)***	*Drafting a vision of EU R&D policy related to these 3 focus areas for 2050 and describing 3 complementary views to reaching the vision. Provide an overview of emerging synergies and trade-offs between the focus areas, anticipate their development in alternative future scenarios and give recommendations for reaching a desired future state.*	*Provide policy support: overcome the fragmentation of EU research area & create clear cut research agenda for Climate action, resource efficiency & raw materials.*	***Trend Analyses, Literature Review, Scenarios, Futures Triangle, STEEP(VL)***
Extract-IT	***LPRC***	***2013***	*Identify emerging and potentially disruptive trends in the use of ICT in future underground mining (timeframe 2050), convert these findings into call for proposals under H2020 future and emerging technologies programme*	*Defining FET research topics supporting the ICT challenges of mineral extraction under extreme geo-environmental conditions.*	***Mindmapping, Delphi Survey, Scenario Exploration***
Polfree Project		***2012-2015***	*Investigate web of constraints on using natural resources efficiently, understand how a resource-efficient economy look like and what are the consequences if this is achieved or not.*	*Exploration of policy mixes for the transition towards a more resource efficient economy.*	

INTRAW Project	*Fraunhofer IAO*	***2015-2018***	*Evaluation of potential future scenarios for 2050 to frame economic, research, and environmental policy towards a sustainable raw materials supply. Identification of likely opportunities and crises. Discuss expected responses to the research demand, technology investments, and economic components of raw materials system.*	*The International Raw Materials Observatory (INTRAW) project is working towards a sustainable future for*	***Scenarios Development***
Mining Scenarios for Colombia	***University of Medellin***	***2014***	*Provide recommendation of strategies that were planned, partially implemented or brand new, a national tool for the mining sector over strategic decisions and for the development of the national plan of mining development.*	*Future of mining in Colombia (UPME/Ministry of Mining).*	***LR, Structural Analysis, World Café, Scenarios Development***
From copper to innovation: mining technology roadmap 2035	***Chile Foundation***	***2016***	*Generate consensus on the future outlook for mining on an internal copper sector level, identifying technological problems and challenges. On an external level, it provides the information to stimulate collaborative research in the academic sector, technology institutes and among suppliers and consulting firms.*	*Chilean reliance on Copper, future demand and technical challenges.*	***Roadmapping***

7.2 Future Raw Materials Challenges

The future is also a product of today's values, drivers and trends, and those can be studied systematically. Foresight studies typically undertake some form of Environmental Scanning (e.g. STEEP) in order to better understand what the relevant factors according to the focus of the exercise is. Some methodologies, such as Scenario analyses, frequently use this approach to support the creation of alternative images of the future, assessing drivers and trends in terms of impact and uncertainty (i.e. Critical Uncertainties). The results of such assessments are context-, timescale- and objectives-dependent; therefore typically each study carries out their own assessment. This section summarises these assessments made during the review of past raw materials foresight case studies. They can provide more practical examples of what kind of drivers, trends, and uncertainties have emerged in a raw materials context.

Table 17 provides an overview of relevant future challenges, namely the drivers, trends, uncertainties and key factors to be considered. Although this is a gross simplification – since the items are not contextualised – they were divided into eight categories to facilitate visualisation.

As part of the review of past raw materials foresight case studies, critical uncertainties were identified in order to construct scenarios within the given foresight methodology framework. Table 18 summarises these critical uncertainties within their respective context. Typically, these studies would select two critical uncertainties – drivers assessed by their degree of uncertainty and impact – and construct scenarios based on two axes, each one corresponding to a critical uncertainty.

Table 17 Overview on raw materials future challenges, drivers, trends & uncertainties.

Socio-economic	Economic	Geopolitical
• Level of sustainability practices • Demographic changes • Changing societal values • Consumer behaviour • Indigenous expectations • Skills gaps • Health & Safety expectations • Artisanal mining • Local communities – Social License to Operate	• Power concentration • Raw materials trade outlook • National (State) position to raw materials • Commodity prices • Access to capital • Financial openness • Global wealth distribution • Fiscal policy • Form of capitalism • Interest rates / Return of investment	• Regional stability • Resource nationalism • Protectionist approaches • Energy security • Quality of public governance • Land-use conflicts • Wars • Policies of producing countries • Taxing & Royalties • Permitting & Regulation
Environmental	**Natural Resources & Technology**	**Research & Governance**
• Response to climate change • Water availability and prices • CO_2 • Industry adaptation and response to environmental standards • Ecosystem and biodiversity valuation • Circular Economy • Resource efficiency	• Marine resources • Fracking, deep sea oil/shale gas • Urban mining's share • Landfill mining • Automatic sorting • Big data • Critical (mineral) material substitution • Green Economy (clean, low carbon tech) • Energy innovation • Level of automation • Resource scarcity • Rate of technological change • Productivity • Declining grades • Discovery of alternative deposits • Share of mining in extreme conditions	• Short term focus • Re-industrialisation • Whole value chain business models • Environmental regulation • Level of R&I cooperation • Intellectual property rights • Evidence for policy • Competitiveness

Table 18 Raw materials foresight case studies – critical uncertainties.

Case Study	Critical Uncertainties	Context
World Economic Forum – Mining & Metals Scenarios to 2030 (WEF 20010)	• Geo-economic Landscape: free markets or closed borders • Geopolitical Landscape: unstable or unstable • Economic Outlook: Strong cyclical growth or stagnation and volatility • Environmental Outlook: decisive and ambitious or reactive and incremental	Financial Crisis, ever-increasing globalization, environmental & Climate Challenges. Stimulate dialogue, provide multidisciplinary perspective insights, context for stakeholders to share their perspectives, provide tools for decision making and collaborative actions.
World Economic Forum – Mining & Metals in a Sustainability World 2050 (WEF 2015)	• Growing concern for the environment • Climate Change • Intensified rate of technological change • Higher demand for social fairness • Increased "democratization" • Abrupt generational change • Rising concerns about artisanal mining • Potential resource nationalization • Mining in remote, undeveloped regions • Declining ore grades	Financial Crisis, more sustainable operations, Sustainable Development Goals Agenda (UN). Provide a framework for supporting major transitions shaping the industry value chain, adjusting critical questions to a more sustainable world. Engage industry stakeholders on the topic, continue development of a transformation map (drivers research, gap identifications), define a roadmap (plan of action guiding to a sustainable world + engagement plans with government and civil society) and outline the circular economy (explore implications for the sector)
Polinares – Future World Images (Clingendael 2012)	• Market or National institutional structure • Market or Strategic-oriented economy	"Future World Images" to recognize the future of geopolitical and geo-economic relations and the impact on Energy and Mineral markets and policies. Done in 2 stages, near future, where path dependency exists and 4 storylines covering the post period to 2040.
Polfree Project (Jäger & Schanes 2012)	• Governance: Conventional or new forms; • Spatial Scope: Global or EU	Exploration of policy mixes for the transition towards a more resource efficient economy. Investigate web of constraints on using natural resources efficiently, understand how a resource-efficient economy look like and what are the consequences if this is achieved or not.
Alternative Scenarios for the North American Mining & Minerals Industry (Institute for Sustainable Development 2002)	• Economic Performance: High or low growth, prices and productivity; • Societal Values: Open, inclusive, holistic or Closed, divisive, self-interest.	Disconnection between practices and values of today's society leading to concerns over the Social License to Operate. Assess global mining & minerals in terms of transition to sustainable development, identify how and if the services provided can be delivered in

		accordance with sustainable development, propose key elements for an action plan. Build a platform of analysis and engagement for ongoing cooperation and networking between stakeholders.
Global Foresight and roadmapping for the development of the rare earth industry in Brazil (Almeida & Moraes 2014)	• Global market: free trade and sustainability (growing demand for REE) or restrictive trade policies and protectionism with controlled demand for REE; • New Technologies: substitute materials for REE, emerging of new technologies not based on REEs or no substitutes for REEs and emergence of more applications based on REEs	Chinese monopoly, Chinese exports quota restrictions, higher prices, increasing demand, limited supply. To structure a long and Medium-term agenda, linked with the development of REE productive application chains.
Long-term future copper scenarios for exploration targeting strategies (Sykes 2015)	• Conceptual search space (for Copper ore): Increased or decreased • Economic margins: increased or decreased	Consensus over the declining copper ore quality, with resource depletion paradigms determining views of long term future. Increasing on general costs can be mitigated with new discoveries. Struggle in scientific and economic techniques to incorporate the multiple external factors affecting the copper mining in the future. How the methodology can begin defining some parameters for the 'undiscovered accessible reserves' - considering the complex interaction of geological, socio-political, environmental, technological and other factors. To compare each scenario with the 20 main copper projects to determine which deposits are the best proxies to guide exploration targeting.
Mining Scenarios for Colombia (UNC 2014)	• Public Structure • Mining Revenues • Level of Corruption • Environmental Sustainability • Communities Behaviour	Provide a national tool for the mining sector over strategic decisions and for the development of the national plan of mining development (UPME/Ministry of Mining)

8. Foresight Applications

8.1 Introduction

Foresight can have a wide range of applications, looking at the future of multiple areas. With regards to the specific European context, foresight has been repeatedly utilised in a variety of projects under the EU science programmes FP6, FP7, and H2020. Since the Raw Materials Initiative (2008), the topic has also been increasingly addressed with different approaches for different purposes, as it was observed in D5.3 (Martins & Bodo 2017).

8.2 Policy-oriented Foresight

Policy-makers are dealing with increasingly complex issues that are highly interconnected and interdependent (da Costa *et al.* 2008). The minerals policy context is a good example. With growing uncertainties and accelerated change, the policies attempting to target specific issues can lead to unintended consequences. As policies are inherently related to the future, foresight can be a means of addressing future aspects as a systematic process combined with strategic intelligence. This approach can improve the anticipatory capacity of policy-making. When addressing policy-making, foresight can be developed for six specific functions (da Costa *et al.* 2008):

- **Informing policy:** by providing the anticipatory 'intelligence' on future challenges and options as input to policy conceptualisation and design;
- **Facilitating policy implementation:** enhancing the capacity for change in a given policy field by building common awareness of the situation of future challenges, as well as of networks among stakeholders;
- **Embedding participation in policy-making:** facilitating the process of civil society participation the policy-making, improving its transparency and legitimacy;
- **Supporting policy definition:** providing more specific options for policy definition and implementations;
- **Reconfiguring the policy system:** it becomes more apt to address long-term challenges;
- **Symbolic function:** indicating to the broader public that policy-making is based on rational information.

Moreover, da Costa *et al.* (2008) suggests emerging guidelines in order to achieve a better impact of foresight on policy-making, these are summarised in Table 19.

Table 19 Policy-making & Foresight – Emerging guidelines (adapted from da Costa et al. *2008).*

Analysis of the policy context	• Foresight in tune with the policy making process; • Good comprehension of the system in which the foresight is embedded as well as the system on which it is supposed to impact; • Position of foresight within the process of policy building, linked with other planning activities.
Shaping within boundaries	• Find the right balance between shaping the future and adapt to constraints of the target area (i.e. country, region, sector or thematic field); • Make sure that expected outcomes are realistic.
Involvement of policy-makers in the design	• Ensure the breaching of the barrier between a "black box", one-way demanding policy-making, and the inclusion of policy-makers in the methodological design phases of foresight.
Involvement of policy-makers in the process	• Assign specific roles to policy-makers that suit their perception of their relationship to the process – define how and when should they be involved.
Adding a policy-definition phase	• "Adaptive Foresight" (Weber, 2006) to go beyond "informing policy" and "facilitating policy implementation", complementing the foresight process with a "supporting policy definition" phase, where the results can be translated in specific policy options and actions; • Protect foresight creative dimension from daily business and constraints of policy definition by actively providing spaces for unrestricted creativity.
Reservoir approach	• A good approach can be to conceptualise and present foresight results as a "reservoir" of knowledge resources and policy options to be considered over the coming years.
Addressing choices and values	• As the normative dimension is important for legitimising policies, foresight has to make explicit the values it is based on and the desirable futures it is aiming at. This can enhance its capacity on impacting policy-making.
"Smart communication"	• Increase the interaction between policy-makers and policy-advisers by setting additional consultation mechanisms at different steps of policy-making, but beware of negative side-effects; • Enhance the quality, relevance, usability and timing of the communication between policy-makers and policy advisors; • High credibility of both policy-makers and policy-advisors due to past productions can improve the reception of the foresight coverage and objectives.

Figure 26 summarises the outputs, outcomes and impacts of a policy-oriented foresight exercises.

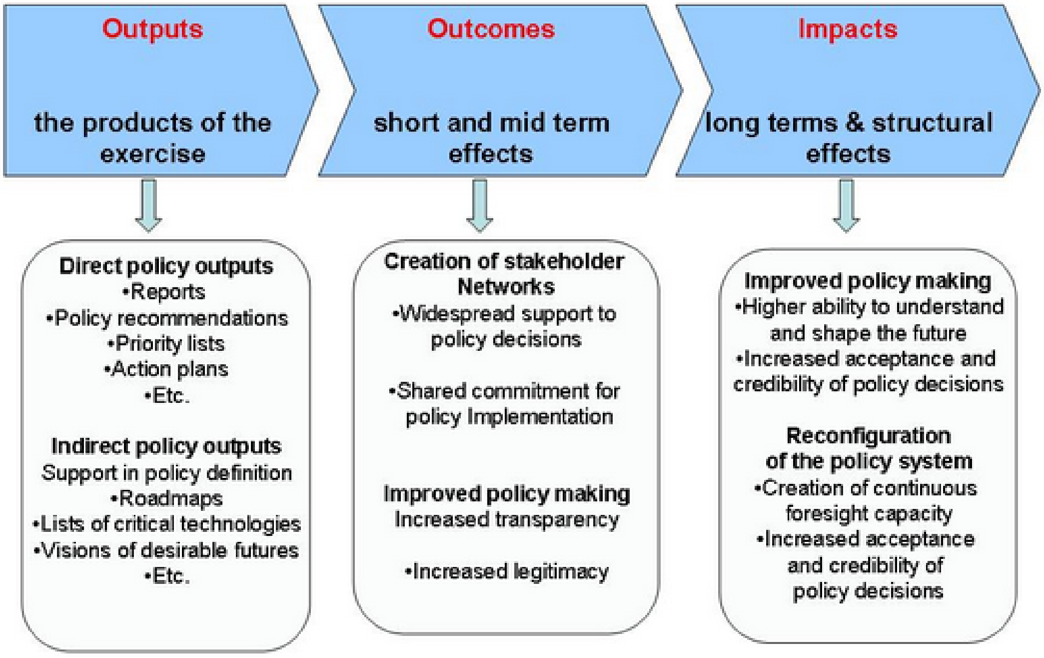

Figure 26 Summary of outputs, outcomes and impacts – policy-oriented foresight (ForLearn 2010).

In practical terms, the first two functions 'informing policy' and 'facilitating policy implementation' are considered to be the core functions of foresight in the policy-making context.
As da Costa *et al.* (2008) states, the products thereof may comprise not only direct policy recommendations (priority lists and action plans), but also contribute to policy design with products such as:

- Scenarios of possible future developments;
- Roadmaps towards different possible futures;
- List of critical technologies; or
- Visions of desirable futures.

In terms of facilitating policy implementation, there is a clear potential for foresight to function as a systemic policy instrument. (da Costa *et al.* 2008).

At the EU level, EFFLA (2013) identified a need for a better integration of Forward Looking and Strategic Activities[12] between the Commission and Member States. For that, a framework (Figure 27) built in four steps is suggested. It provides a clear view on the link between forward looking activities and the processes where formal decisions regarding strategies, selection of priorities and design of their implementation are made.

[12] All activities providing future oriented strategic intelligence, i.e. activities where the results of strategic intelligence are analysed, made sense of and based on which evidence-based options are created.

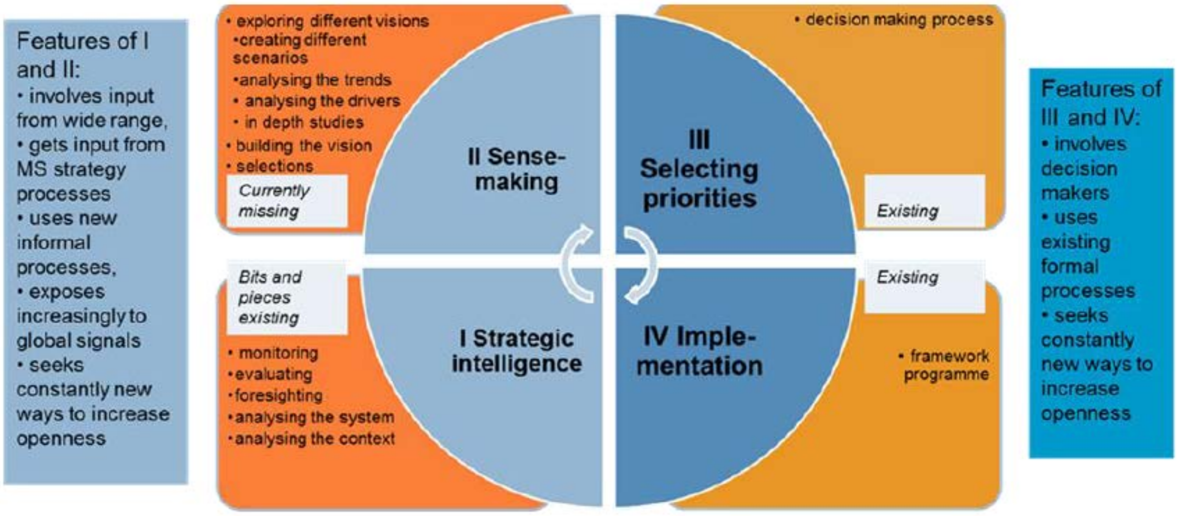

Figure 27 Necessary elements of the future EU strategic process (EFFLA 2008).

In the context of 'Strategic Intelligence' Kuosa (2014) provides an illustrated overview (Figure 28), summarising the core objectives, duties and products of different types of organisations that try to identify and tackle existing or emerging issues. This overview is divided into four layers:

- Situational awareness,
- Understanding the process,
- Options for actions and strategy; and
- Policy-making.

The 'situational awareness' represents the direct knowledge gathering level and horizon scanning practices. The main objective is to provide real-time, early warning knowledge for the policy-makers. The 'understanding the process' level seeks to uncover and analyse the driving forces behind emerging issues. Foresight is scoped under the strategic level of 'options for actions and strategy'. According to Kuosa (2014), it systematically supports the creation of strategic options, scenarios and comprehensive overview over the situation and visions for policy-makers. Furthermore, it allows for 'out-of-the-box' prospections by both, normalising views and systematic general questioning via 'what-if' type of questions, counter-arguments and generation of wild cards.

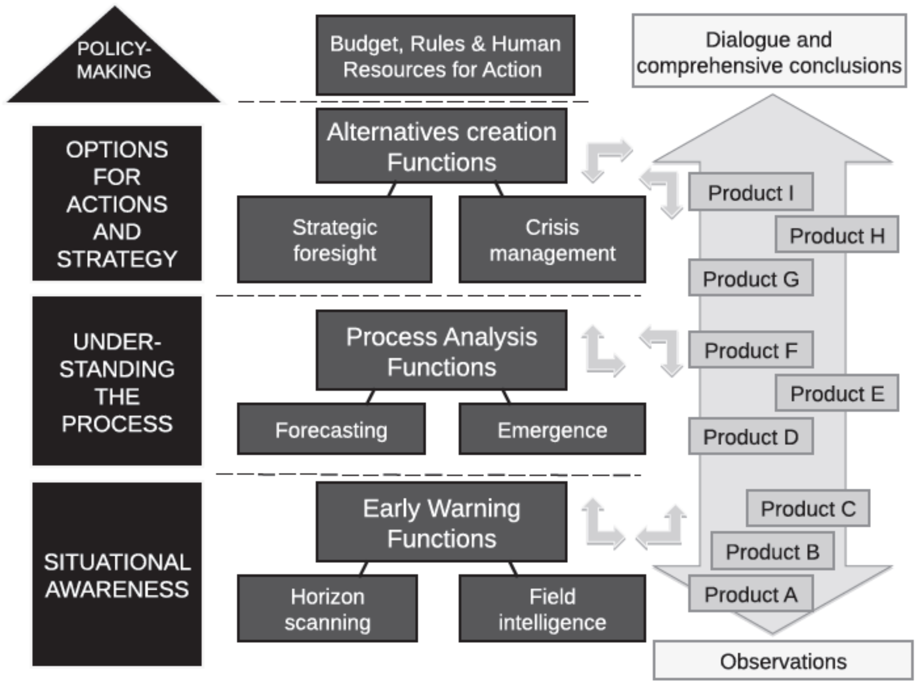

Figure 28 Layers of action – Summary (Kuosa 2014).

8.3 Strategic Raw Materials Intelligence Approaches – Foresight

Strategic Intelligence typically deals with national or corporate long-term strategic issues (Kuosa 2014). Its main functionalities are intelligence, strategic foresight and visionary management. Strategic Intelligence is staged in a phase of improved awareness of and information about key drivers of change, implications of developments and options for actions (Keenan *et al.* 2003). Foresight is particularly important for strategic intelligence, as it offers the possibility of envisioning the future and generating shared visions, enhancing the strategic intelligence capacities.

Raw materials intelligence is of great importance for developing a comprehensive minerals policy-making framework (Falck *et al.* 2017). In this context, foresight can increase the efficiency and effectiveness of the EU activities related to raw materials policy planning.

As stated in D3.1 (Petavratzi *et al.* 2017) "Raw Materials Intelligence is not just about having the knowledge to provide answers to questions, but also about asking the right questions". To reach the 'intelligence' level (Figure 29), several steps and iterations have to be undertaken to obtain the data required, define the ideal methods and tools and enable the exploration of the issues at stake. At a strategic level, foresight can complement the process of generating intelligence to consider the longer-term future and inform policy-making in a timely manner.

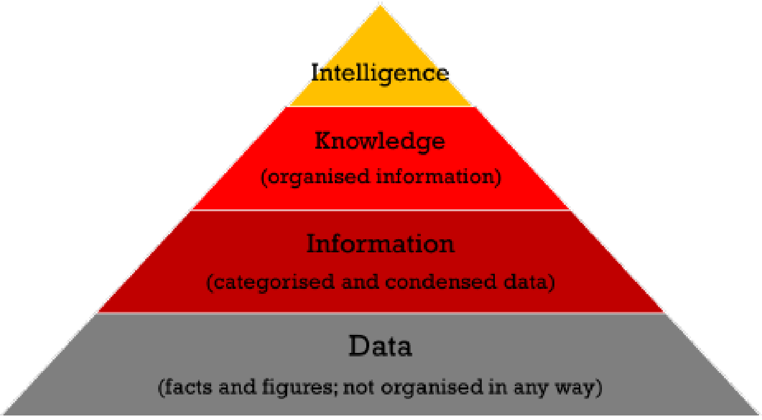

Figure 29 From data to intelligence.

The following scheme, Figure 30, proposes a visualisation of the raw materials intelligence context and the different levels of actions therein.

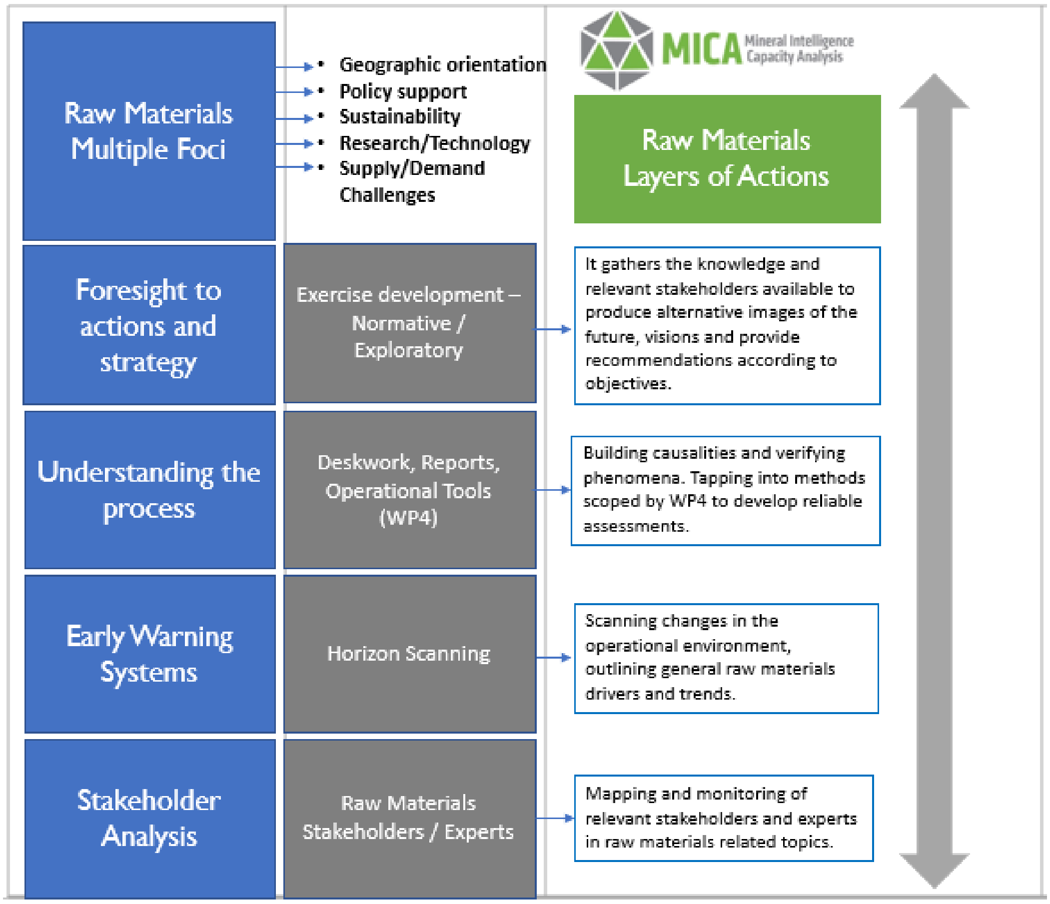

Figure 30 Layers of action – Strategic Raw Materials Intelligence.

To illustrate this in the context of foresight approaches and methods, Kuosa (2014) suggests the *U-curve of actions in futures domains* presenting the three levels that exist in Foresight (Figure 31) as well as corresponding objectives clusters.

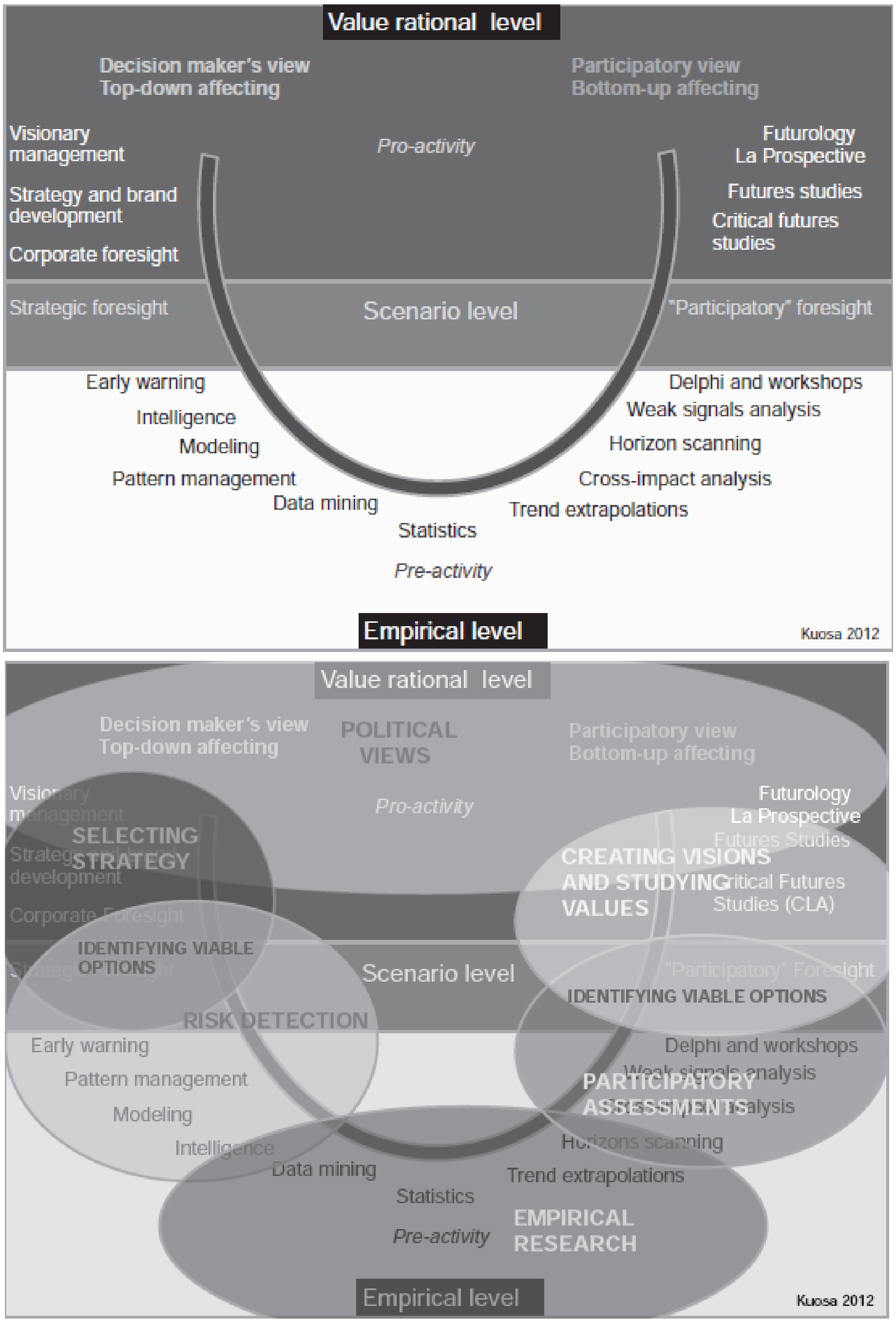

Figure 31 U-curve of actions in futures domain & objectives clusters (Kuosa 2014).

9. Raw Materials Foresight Framework

9.1 Overview and suggested schemes

As the previous chapter provided a basis for understanding important foresight and strategic intelligence concepts, as well as placing the raw materials into context, specific frameworks can start to be synthesised in order to provide a more straightforward outlook on the possible approaches. Though such undertaking can never be exhaustive or comprehensive enough, it can set a good starting point for designing a foresight process. The following scheme (Figure 32) attempts to support the conceptualisation of the foresight exercise and also to provide a good overview over possible approaches and alternatives.

This section further explores possible methods and combinations of tools with regards to the objectives and outputs these methods can provide, together with theoretical and practical examples.

Bringing Chapter 4 into perspective, a sequential process can be outlined for understanding one's context and needs, and translating it into a foresight process. Defining the topics under scope and objectives of the foresight study are the initial steps illustrated in Figure 32.

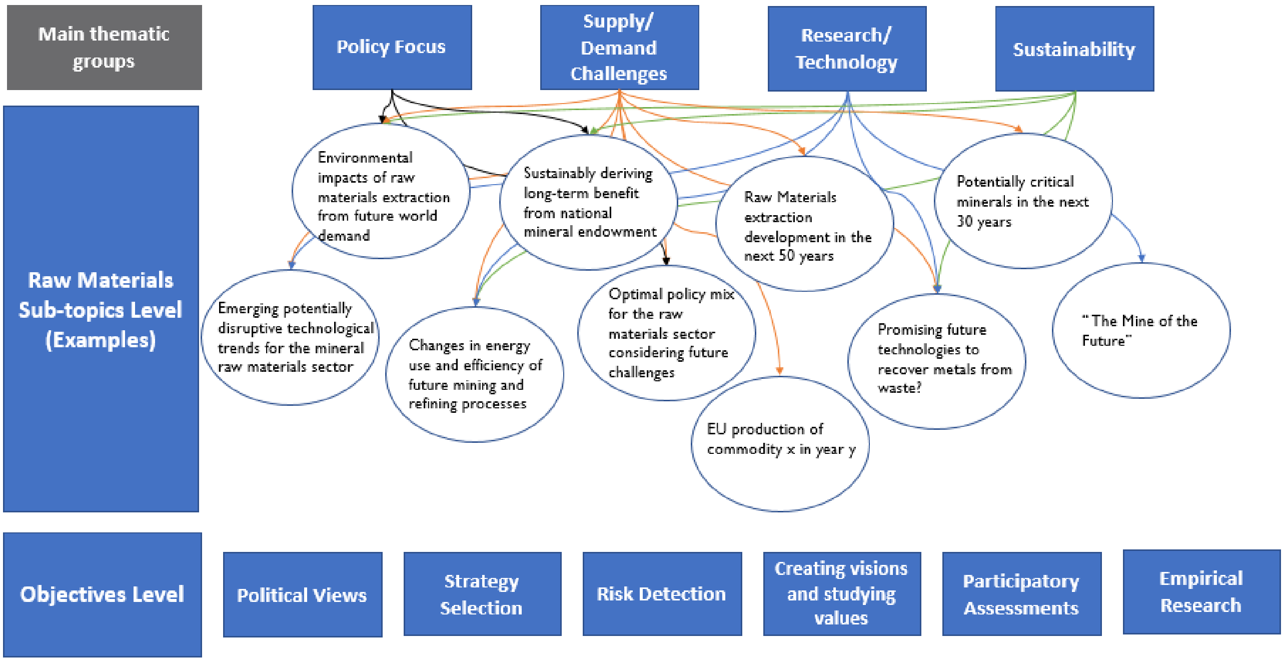

Figure 32 Raw materials thematic clusters, topics and objectives clusters.

Once this is assessed, a brief checklist can follow, which is largely related to one's context and therefore it is variable and hard to map in a straightforward manner. This step is summed by Table 20.

Table 20 User Context Checklist.

Foresight Scoping	User Context
User	• Background o Public sector o Private sector o NPO o Academia • Level of expertise o Foresight o Topics under scope
Perspective	• Confined • Techno-economic • Holistic
Approach	• Top-down • Bottom-up
Time Horizon	• 10-40 years
Timeframe	• Punctual to large • Continuous

Once the users possess a good comprehension of their needs in terms of foresight, they can move on to designing a foresight methodology accordingly.
At this stage, a quick reflection can already provide a glimpse on the myriad of methods that can be used according to the different objectives. Table 21 samples such exercise.

Table 21 Comparison of methods and use (adapted from Gordon & Glenn 2004).

Do I need to…	Methods (Examples)
…collect judgements?	Delphi Futures Wheel Expert Panels
…forecast time series, and other quantitative measures?	Econometrics Trend Impact Analysis Structural Analysis
…understand the linkages between events, trends, and actions?	System Dynamics Agent modelling Trend impact analysis Cross impact analysis Futures Wheel Causal Layered Analysis
…determine course of action in the presence of uncertainty?	Roadmapping
…portray alternative plausible futures?	Scenarios Futures Wheel Agent Modelling
…track changes and assumptions?	Environmental scanning

Figure 33 sums up a framework of foresight components against different foresight (exercise implementation) stages, and its implications for potential methods to be used. For comparison, the 'generalised layered methodology' from Voros (2003) is also featured.

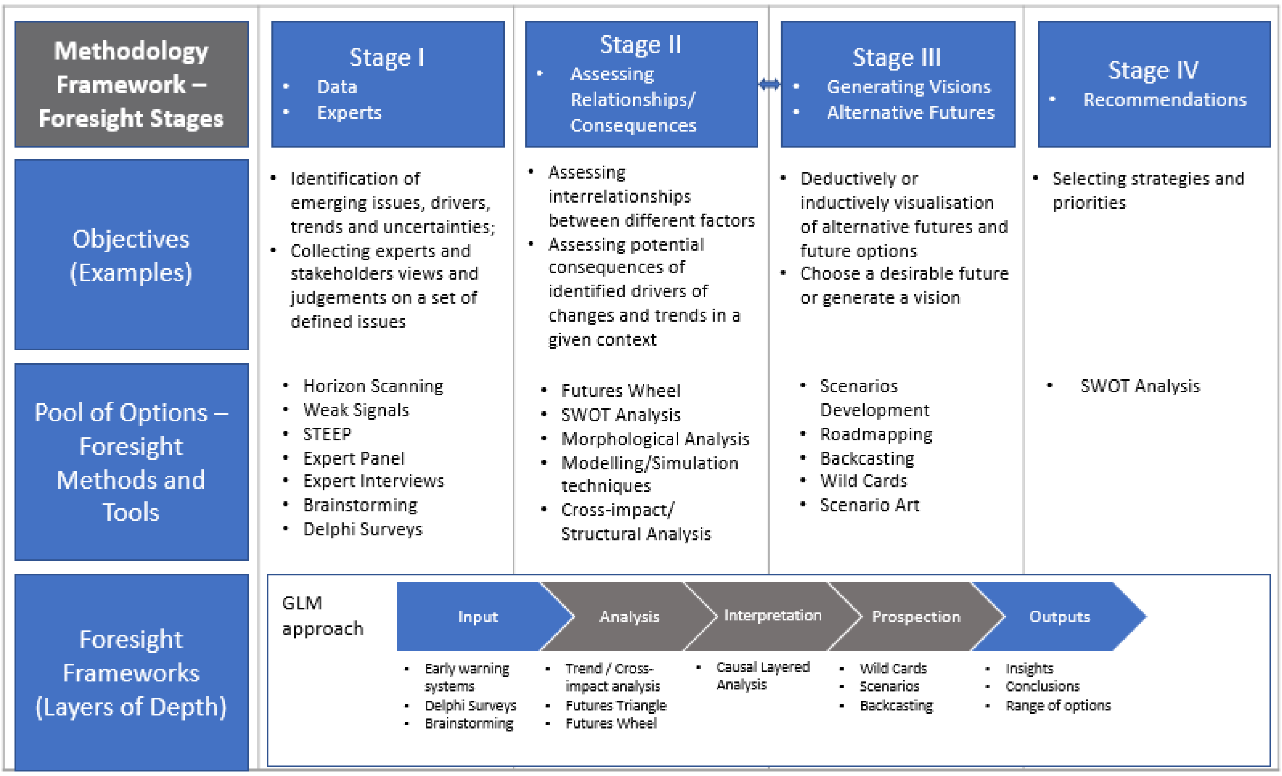

Figure 33 Methodology Framework schema – Foresight Stages.

Although the Foresight process can be somewhat fixed, there can be often feedback loops of inquiry to the methodological framework, as well as 'modular' approaches, which in turn make the process less 'linear'. The stages are defined as:

- **Stage I**: Focus on people and data gathering. Methods at this stage might rely more directly on data and/or qualitative inputs from experts. They will support the identification of initial relevant factors according to the scope and objectives of the project;
- **Stage II**: As the relevant factors are brought to light, the second stage can analyse their interrelationships and consequences, setting an important view on potential future developments. This stage can require more interaction-based, multi-disciplinary approaches.
- **Stage III**: This stage is the generation of alternative futures. It may frequently feature workshops with a broad involvement of stakeholders and creativity-based approaches. Furthermore, it is also a point to define – or refine – a preferred future, and different pathways to get there. This can provide more robust insights to be assessed in the last stage.

- **Stage IV**: The last stage is focused on the outputs of the foresight process. It should focus on delivering the message clearly to the client. Typically, recommendations will be provided, shedding a light on both, the foresight process insights and outputs and also the objectives initially defined. Translating this into clear, timely and robust strategic recommendations is the main goal of the step.

Stages I and II might require feedback loops to refine the 'picture' of the issues at stake, whereas Stages III and IV might be undertaken interchangeably as consequences. Insights and potential recommendations can emerge also across the different stages.

To bring such framework to the context of raw materials, another scheme is suggested, covering identified thematic clusters in raw materials related foresight exercises. These thematic clusters are not considered individually; a foresight study can explore multiple sub-themes of different clusters.

A 'scenario level' is also featured. Although not mandatory, Scenarios Development can always be used for generating alternative images of the future. The components of the scheme (Figure 34, page 78) are defined as:

- **Geographic Orientation (e.g. 'National Benefit')**: deriving national benefit from mineral endowment is a common objective of raw materials foresight. It can, though, focus on a regional or supra-national scale instead. It typically aims at developing a common future vision bringing together various stakeholders in a process that can extend over years of work and outreaching a wide range of actors.
- **Paradigm shift:** it sets a normative case for 'paradigm shifts' to the raw materials sector. Although it can explore future implications of the industry's adaptation to new standards, it is more often a case of setting a vision for a more sustainable future for the raw materials sector. Nevertheless, foresight studies focusing in 'paradigms shifts' in the interface between strategic and operational levels of the industry and sector (e.g. Industry 4.0) were not yet observed.
- **Research/technology-focused**: It can entail two approaches – technologies that can somehow affect the raw materials sector or implications of technology to specific (groups) of raw materials.
- **Stakeholder Engagement**: It can be considered a side objective of foresight processes as the ability to act and shape the future is enhanced by connecting the system together and understanding the different perspectives that make up the field under study. Interaction-based methods are extremely useful in unleashing the potential of optimal cooperation and synergies.
- **Supply/demand challenges**: this can be seen as a broad thematic cluster as it encompasses topics that are somehow related to the provision of raw materials. From primary production, including the mineral exploration and the mining sector, through recycling and waste as secondary production. There is a growing concern over the future supply of raw materials and topics such as resource scarcity.

- **Policy Support**: policy-making requires sound intelligence and evidence-based products to properly explore the futures with foresight.

- **Scenario level**: it suggests Scenario methodological approaches that are more suitable for the theme under analysis.

- **Focus**: mainly related to an object under study – it can focus on a single commodity or reach a broad (raw materials) sectoral perspective.

- **Resources availability**: as methodological approaches are shaped by many factors with regards to the user's background (Section 9.3), the proposed simplification ranges from a broad availability of resources and access to stakeholders to a more constrained one. Involving numerous stakeholders and workshops would typically incur a longer time-frame for the foresight project and higher financial costs. A constrained set of resources usually limits the options in terms of methods and approaches that can be used.

9.2 Methodology Catalogue

This section further explores possible combinations of foresight methods and tools, providing a basis for understanding how methods can be combined according to generic or specific objectives. Figure 35 (page 80) samples some possible combination of methods ('routes') followed by a brief description of each possibility. These are not rigid rules for how to combine the methods, but it can be useful to understand the mechanism of choosing and combining them for a given purpose. It is worth mentioning the possibility of 'modular' approaches, where the methodology framework of the foresight entails sub-sets of methods in a sequential manner. There is a vast amount of possible combination of methods and is virtually impossible to map all of them. However, certain combinations and uses are more commonly observed in past case studies and also have a strong theoretical appeal. Figure 356 provides an overview over the methodological 'routes' against the backdrop of the different foresight stages. These 'routes' are described in more detail below. Setting these examples can be helpful for potential users by providing a basis for exploration and inspiration for further applications.

Route 1

Enables the identification of trends (STEEP) and the further analysis of potential consequences (Futures Wheel + Delphi).

Route 2

Expert inputs (Delphi Survey) can improve the construction of the diagram (morphology). Conversely, Morphological Analysis can assist in defining the questions for the Delphi Survey.

Commodity (Focus)	Single Commodity ⟷ Sector at large		
Resources availability	Constrained ⟷ Broad		
Main thematic groups	**Geographical Orientation (e.g. 'National Benefit')**	**Paradigm shifts**	**Research/ Technology**
Scenario Level	Normative, vision- and key factor-based. Consider Backcasting approach.	Normative, vision- and key factor-based. Consider Backcasting approach.	Normative or explorative. Consider combination with Roadmapping.
Foresight Implications – Access to resources and stakeholders	Typically seeks vision-building processes, with strong normative appeal. Combination of different methods through different sources of knowledge, with a strong interaction- and creativity-based component. A "Layer of depth" framework such as the 'Six Pillars' approach, can be helpful on digging deeper levels of understanding of issues identified with the perspective of re-orienting or setting a future vision.	A normative, participatory appeal can be applied to build a future Vision of the sector or a specific context shaped by sustainability paradigms such as circular economy and resource efficiency and to create viable options towards it. Broad participation can be highly advisable for enabling this. Qualitative, creativity, interactive-based methods are suggested. Evidence-based methods such as modelling can help measure relevant causal effects and relationships.	Expertise-based methods can be highly advisable. These methods can be combined with Roadmapping and normative scenarios for exploring future developments of technologies emerging in a raw materials context. A more explorative approach could be related to examining the implications of emerging technologies to the sector. Delphi survey and trend analysis surge as options to better understand these implications.
Main thematic groups	**Stakeholder Engagement**	**Supply/Demand Challenges**	**Policy Focus**
Scenario Level	Exploratory, qualitative, key factor-based scenarios.	Exploratory, key factor-based scenarios. Consider Wild Cards.	Normative or explorative.
Foresight Implications – Access to resources and stakeholders	Set up of ongoing early warning systems (horizon scanning) can monitor supply issues and risks of RM deemed more critical, combined with the operative tools (scoped under WP4). Triangulation approaches considering qualitative, quantitative, evidence and expertise-based methods can support the development of the Foresight exercise with a view to identify strategic options.	Consider the set up of ongoing early warning systems (horizon scanning) to monitor supply issues and risks of RM deemed more critical, combined with the operative tools (scoped under WP4). Triangulation approaches considering qualitative, quantitative, evidence and expertise-based methods can support the development of the Foresight exercise with a view to identify strategic options.	Exploratory approaches can serve as an open-end product for policy-makers to explore policy options. Should it support policy definition, methods and tools such as Scenarios, Backcasting, Roadmapping and SWOT analysis can enhance the capacity of translating the foresight outputs to the definition of e.g. priority lists or action plans. Evidence-based and creativity-based methods are strongly suggested.

Figure 34 Raw Materials Foresight Framework.

Route 3
Scenarios exploration to identify relevant issues in the national minerals sector. Assessing consequences of the pre-identified key issues (Futures Wheel), engaging participants in visualising a preferred future (Scenario Art), delving into the issues with Causal Layered Analysis and Futures Triangle to help framing a future vision and Back-casting from that Vision to understand how to get there.

Route 4
The model (System Dynamics) can reflect the effects of interacting external events (Cross-impact analysis) – it turns a deterministic model into a more probabilistic one.

Route 5
Multi-assessments of the Scenarios assumptions through Serious Gaming, Roadmapping and SWOT analysis.

Route 6
Scenarios highlighting the technological developments featured in the roadmap, illustrating what these developments mean for the society and business. Specific commodities studied bringing global aspects to a national level with roadmapping for specific applications, providing related technology & innovation policy recommendations.

Route 7
Scenarios to provide the backdrop for an assessment of specific assets and SWOT analysis converting this Scenarios analysis into strategy. Specific commodities (e.g. copper) studied testing operating mines against different future scenarios, 'wind-tunnelling'[13] for the more robust ones.

Route 8
Trend Analysis used to provide information on drivers, critical factors and variables, supporting the development in parallel of both, model and scenarios. For the latter, Experts Interviews were also used for identification of key factors.

Route 9
Scenarios produced in a normative manner with Back--casting of pathways towards a preferred future supported by expert interviews. Developing a framework for a sustainable world in 2050 placing the mining & metals sector in context, testing it for a circular economy 'case study'.

[13] The term 'wind tunnelling' in this context refers to the act of testing the different strategies against the different scenarios.

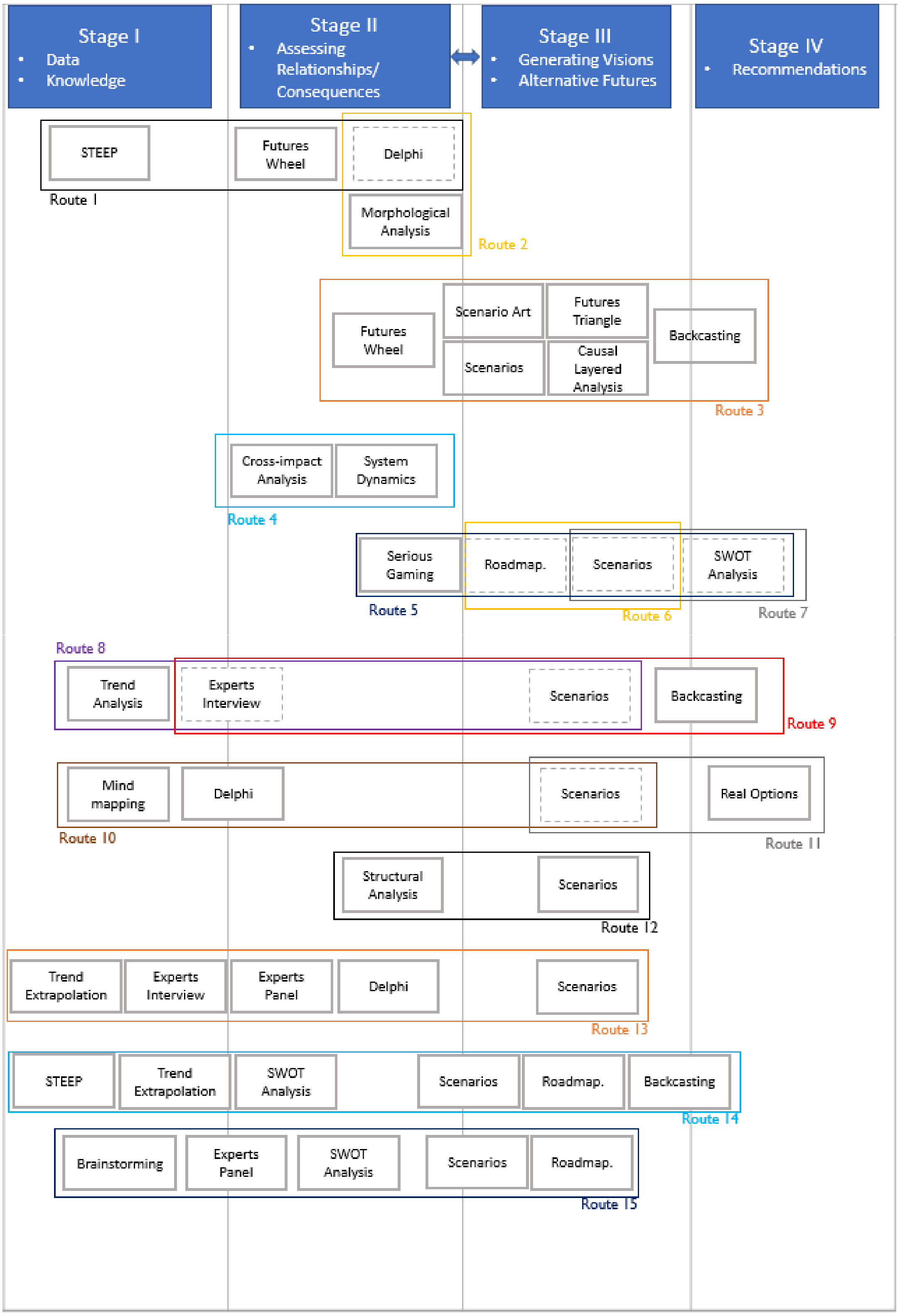

Figure 35 Raw materials foresight sample routes.

Route 10
Mind-mapping to understand the system to be analysed. Scenarios can be then explored to put them into context and help developing a Delphi Survey. Delphi rounds can provide good development pathways for recommendations. Specific technological requirements under different futures (Scenarios) can be appraised through Delphi Surveys for recommendation on related research priorities.

Route 11
While scenarios help to provide a backdrop for considering alternative futures, Real Options analysis can help orienting a better allocation of capital and investments. This 'Shell approach' – as we can trace analogies between the oil & gas and raw materials sectors – is appealing in terms of dealing with long term investments in highly volatile and discontinuous scenery. By combining the traditional scenario development with real options analysis, the company develops the capacity to commit business planners to increase their futures horizon to act in the light of uncertainty and complements it with a better oriented selection of investments and efficient allocation of capital (Mann & Jannek 2008, Cornelius *et al.* 2005).

Route 12
Structural analysis determining the causal effect among (uncertain) variables, enhancing the development of the scenarios. Exploring the future of the mining sector at the national level.

Route 13
Mapping research and innovation capacities with expert's interview, trend extrapolation. Experts Panel for identifying R&I options and define Delphi statements. Run a Delphi survey and generate Scenarios to test options. Recommendations through prioritisation of R&I options.

Route 14
Environmental Scanning, Trend extrapolation and SWOT analysis for producing a current status report. Scenario development for exploring the nature of issues at stake, generating alternative future images and setting a preferred vision (scenario). Back-casting of the preferred scenario for drafting a roadmap. Recommendation stage with a strategic plan with targets and tasks.

Route 15
Scenarios exploration over alternative R&I futures. Expert Panels and Brainstorming for generating a SWOT Analysis for future R&I management and investments. Setting a vision/preferred future and undertaking a Roadmapping exercise.

9.3 MICA online platform (EU-RMICP) & Foresight

This report proposes a process for 'Raw Materials Foresight Intelligence' in the context of the MICA online platform (EU-RMICP); see Figure 36. The process can be divided into four main steps:

- (Future-oriented) queries: as end-users have specific questions and needs related to future projections, foresight intelligence will be related to the platform's answers to such questions;
- In a first level, information (fact- and docSheets) related to foresight concepts, frameworks methods and tools will be presented, offering the possibility to the user to better understand how foresight can help in answering the question, as well as informing on how to adapt or reshape the question in function of the foresight scope. Advanced users of foresight may skip such step.
- In parallel, data and sources of relevant data may also be provided as answer to such questions that, in a foresight context, can serve as input for the process, as well as on the application of the foresight methods and tools;
- Finally, the platform can also inform on past raw materials case studies, setting potential references for the users to explore according to their needs.

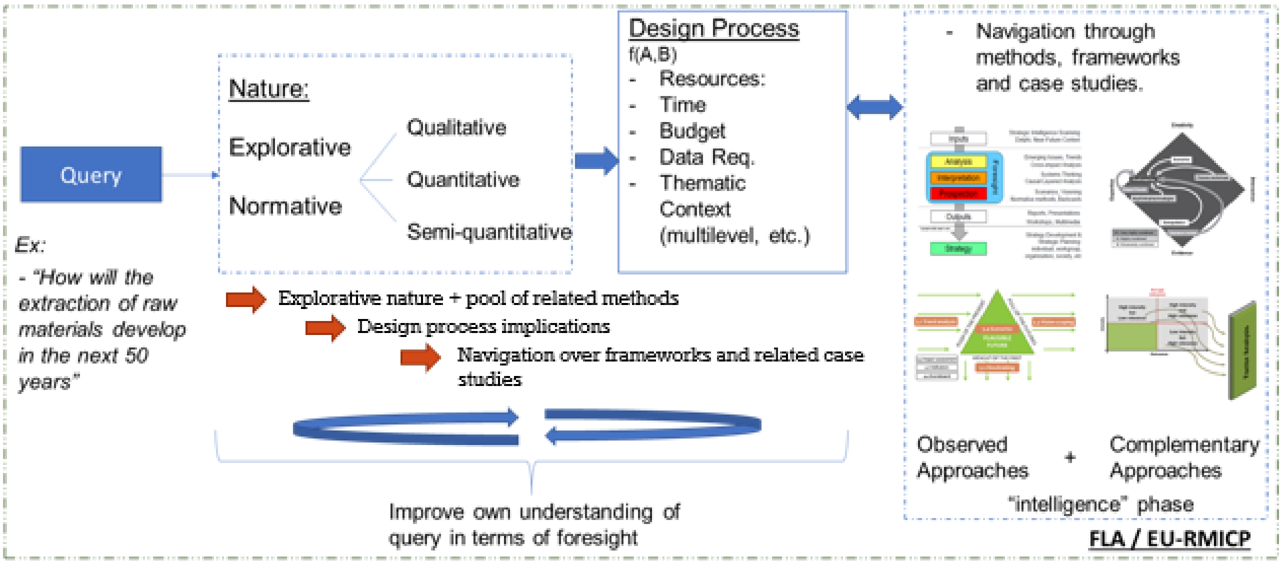

Figure 36 Schematic overview on the process of foresight & the MICA online platform.

For the purpose of illustration, Table 22 explores such approach from a few identified stakeholder questions.

Table 22 Hypothetical process of forward-looking queries in the context of MICA online platform.

<table>
<tr><th>Question (examples)</th><th>(Possible) Foresight approach</th><th>Data Sources</th><th rowspan="5">Past raw materials foresight case studies overview – setting references</th></tr>
<tr><td>How will the extraction of raw materials develop in the next 50 years?</td><td rowspan="4">General concepts and methods and tools will be outlined, including potentially ‘interfacing’ methods drawn from WP4 (operational tools)</td><td rowspan="4">Relevant datasets providing evidence, information and knowledge.</td></tr>
<tr><td>What are the environmental impacts of raw materials extraction of the future world demand?</td></tr>
<tr><td>What will be the changes in energy use and efficiency of future mining and refining processes?</td></tr>
<tr><td>What are promising future technologies to recover metals from waste and what are the costs?</td></tr>
</table>

10. Raw Materials Foresight Recommendations

10.1 Summary

Foresight is not only about utopian or dystopian future visions. Insights can be generated in all phases of foresight with tangible and intangible outcomes.

Future studies are often undertaken in a context characterised by disorder, diversity, interdependence with turbulent environments, and instability (Kreibich 2006). As observed by Kosow & Gassner (2008), methodological approaches should account for integrating discontinuities into future developments – improbable, undesirable or even 'unthinkable' aspects should not be neglected. Complementary methods such as Wild Cards are particularly useful in that sense. More experimental and adaptive forms of foresight processes that are properly embedded into the decision-making context can translate into robust methodological approaches to provide a solid response in such context. More integrative approaches of foresight and strategic raw materials intelligence can provide the appropriate knowledge combined with visions and alternative futures for the policy-makers to make the 'right' decisions. In that sense, decision-making processes should be understood better and brought to the scope of the Foresight study so as to improve its capacity to generate useful outputs. For instance, although mining has not been traditionally an early adopter, technology breakthroughs can occur (and can be foreseen) in shorter time-frames, as the rate of technological change increases. This has implications for foresight studies with a 10-20 years' time horizon, as acknowledging this current feature can improve the credibility of the study. Köhler *et al.* (2015) presents a potential avenue for foresight adaptation, which can be further explored for the raw materials context, especially in issues such as 'Supply Risk'. The report suggests a tool for supporting agile and adaptive foresight processes as part of policy development through a platform that enables real-time interaction with stakeholders by utilising forms of analytical modelling in a transdisciplinary, systemic and participatory process.

Complexity Science can be acknowledged as a promising field in the context of strategic intelligence (EFFLA 2013). As an evolving field over the last decades, it seeks to understand, predict and influence behaviours of complex systems by dealing with nonlinearity, discontinuities, emergence and aggregated macroscopic patterns, rather than with causal microscopic events (OECD 2009). Raw materials foresight could benefit by adding alternatives for dealing with uncertainties and shaping future developments, as such approaches, including systems analyses and modelling, are currently not observed to a great extent in relevant raw materials foresight publications.

There is no formal or systematic Foresight programme to address raw materials future challenges at the EU level. As it was observed in Section 8.3 (Figure 30), additional levels of action are to be considered: a comprehensive understanding of the stakeholders' arena and the setting up of early warning systems generating timely products can improve the basis and capacity to the set-up of manifold raw materials foresight exercises. The MICA project sets an important reference for stakeholders mapping in a raw materials intelligence context. Furthermore, as an intelligence platform it can be a valuable tool for stakeholders to build customised strategic raw materials intelligence approaches.

10.2 Raw Materials Foresight SWOT Analysis

A SWOT analysis (Table 23) supports the evaluation of the foresight approaches in the raw materials context. The context considered for this analysis is related to foresight as a product against the raw materials sector at large.

Table 23 SWOT analysis.

Strengths • In a cyclical and sometimes rather uncertain sector, foresight can help to improve the understanding of the system's complexities by bringing together different stakeholders and systematically looking into long-term alternative futures. It can provide a sound basis for developing robust strategies and supporting successful policies development; • Foresight has currently a wide community of practice at the EU level, with relevant production and mapping activities related to foresight past experiences.	**Opportunities** • The emergence of paradigms (Sustainability-related, Industry 4.0) challenges the current *status quo* when looking into the longer-term future, making a 'normative' case for organisations and policy-makers to approach these paradigms with foresight in the raw materials sector. • Current shifts in political establishments and uncertainty in political stability of traditionally stable countries and regions open lines of questioning possible futures and related challenges. Topics such as raw materials supply risk gain in evidence and appeal. • Improvement in practices and technologies e.g. "Mine of the Future" concept can open-up different possibilities. Foresight can support the exploration of futures and help understanding how to ensure such preferred futures. • Secondary production of raw materials although considered in some foresight studies are still mostly underrepresented.
Weaknesses • Although this has been improving at the EU level in recent years, foresight has not been systematically applied in the raw materials' wider context. Systematic Foresight programmes for Raw Materials at the EU level do not exist to this point. Also, it did not reach the raw materials general public and potential users in its basic definitions, concepts, and terminologies. It lacks awareness of its potential and outreach of the foresight "language", thus losing the momentum of rather sparse raw materials foresight studies and /or initiatives.	**Threats** • As a participatory process, foresights benefits from involving a wide range of stakeholders and create benefits such as generating or improving networks and possible cooperation. Isolationist tendencies and hidden agendas can difficult the foresight processes and might supress the transparency of interests from involved stakeholders; • A disbelief from the general raw materials public and potential users of the foresight benefits as a sense of 'unpredictability' increases. Lack of communication and outreach of foresight potential and products can deem it as irrelevant.

10.3 Ideas for future actions

Many actions can be suggested to improve the foresight practice in the raw materials sector, though they are also dependant on the context of the user. This section outlines some actions that can enhance Foresight capacities at the EU level, to be implemented by actors, such as the European Commission and raw materials focused organisations seeking to develop tailored foresight studies:

- Set up of early warning/horizon scanning capacity for raw materials, especially related to topics such as 'supply risk'. Such necessity was similarly acknowledged by Lee *et al.* (2012). They note that threats posed by natural disasters, conflicts, market shocks and price volatility can thus be better anticipated. Such approach linked to robust decision-making processes (e.g. strategic raw materials intelligence) can effectively increase the capacity of preparing strategies and taking decisions regarding the relevant issues. As mentioned in section 10.1, Köhler *et al.* (2015) offers a potential avenue for such adaptation.
- Improve the attention to the future of specific topics such as secondary resources and resource governance with explicit foresight components e.g. the future of mining wastes.
- As the EU has been consistently improving its capacity to deal with raw materials issues since the launch of the Raw Materials Initiative in 2008, normative foresight studies can become more appealing for suggesting how to envision a desirable future and "how to get there".
- Important initiatives, such as the EIT Raw Materials, identify and offer targeted programmes related to raw materials and can prompt the inclusion of foresight planning in forward-looking projects and R&D initiatives across the raw materials value chain.

11. Conclusion

Foresight has a crucial role in strategic raw materials intelligence. It can increase capacities for timely responses to anticipated futures by identifying major trends, uncertainties, driving forces and needs for future research and it can improve the network of stakeholders and experts. Furthermore, it supports recommendations and proposal of actions to be taken today in order to shape the future.

Several factors can influence the foresight methodology design and should be acknowledged and accounted for. Internal factors are related to the objectives and the accessibility to resources for the foresight user, as well as broad options of methods available, while external factors relate to the context and needs of the user. This Raw Materials Foresight Guide puts these internal factors in perspective, as it conceives the contextual outlook for raw materials, through thematic clusters and previous foresight case studies assessment.

Internal and external factors can evolve into the future, replicating such condition to foresight approaches and recommendations. Stakeholders' needs may change and novel foresight methods and approaches can emerge, facilitated by technological advancements and new practices brought to test. It is, thus, to be said that any foresight guideline is not rigid or fix. Foresight is an evolving practice itself and better comprehending its nature together with a solid contextual appraisal can set the reference and basis for further exploration. By extent, pros, cons and opportunities can be constantly changing, surging and being surpassed (Figure 37).

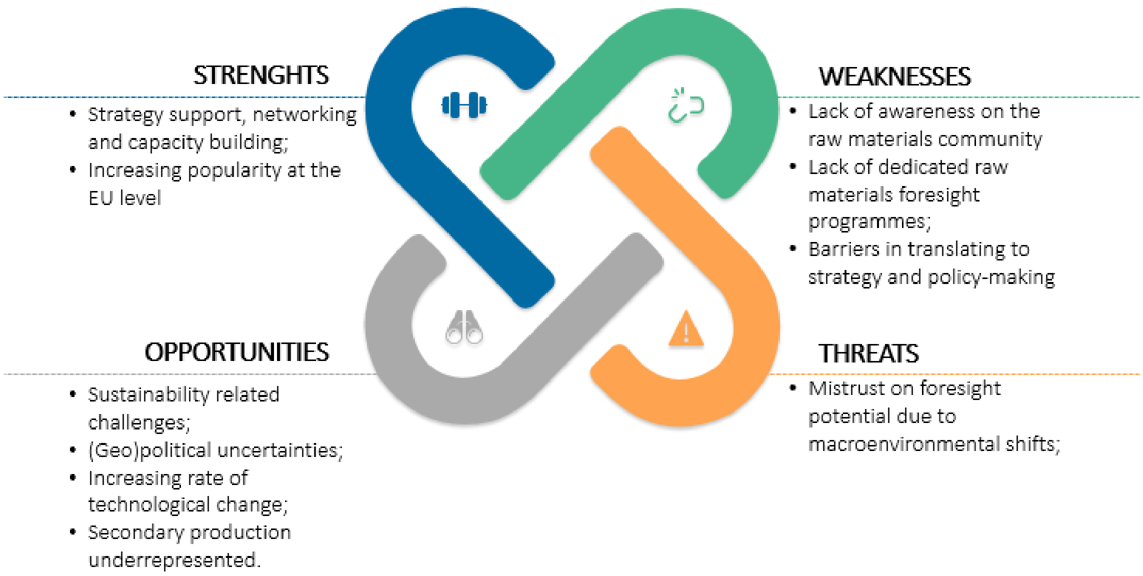

Figure 37 Foresight SWOT Analysis.

With an increasing rate of technological change and of complexity in the world, novel and adaptive foresight approaches are not only possible, but likely to emerge. This, however, will not necessarily change the traditional stages of foresight exercises: collecting/using (big) data and knowledge, identifying relevant drivers, trends, evaluating key factors and creating future images to support the provision of recommendations or definition of strategies.

In sum, foresight is context- and time-horizon-dependant. It is of crucial importance that the user is able to evaluate the suitability of foresight to its needs. Moreover, a detailed understanding of the context where the user is operating and its forward-looking goals can serve as proxies for identifying the most suitable foresight approaches. The Raw Materials Foresight Guide sets important references for translating the users' realities into possible foresight approaches. As discussed in section 9.3, the MICA online platform (EU-RMICP) will be a tool for guiding the user through relevant data, information, methods & tools available – including strategic ones, such as foresight, whenever the stakeholders identify forward-looking needs.

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Appendix A – Raw Materials Foresight Case Studies Inventory – Summary

Mineral Futures Collaboration Cluster (2013)

In the context of the Australian mining industry sustainability over the last mining boom driven by aspects such as declining ore grades, shifting operating environments, globalisation, climate change, evolving community expectations, the project was divided into 3 streams of research: i) commodity futures – how might global supply, demand and consumption patterns change? ii) regional futures – how will future mining investments affect social and economic capital through transitory land use change? and iii) technology futures (what technology is required and what will be the impacts?). Foresight used into long-term strategic challenges, future scenarios, social, economic and regional contexts- transforming Australian minerals landscape with technology & innovation. Two future workshops provided the floor for exploratory and vision building foresight approaches employing a variety of foresight methods.

Methods & tools used: Material flow analysis (ref. WP4), Megatrends, Scenarios, Futures Wheel, Scenario Art, Causal Layered Analysis, Futures Triangle, Backcasting and Literature Review.

Mining & Metals in a Sustainable World (2015)

The aim of the exercise was to provide a framework for supporting major transitions shaping the industry value chain, adjusting critical questions to a more sustainable world in the context of previous financial crisis and sustainable development goals agenda (UN). By engaging industry stakeholders on the topic, the exercise followed the identification of drivers and gaps, defined a plan of actions guiding to a sustainable world and explored the implications of the circular economy for the sector. Several workshops were held to undertake the exercise and build scenarios supported by additional tools such as experts' interviews and back-casting.

Methods & tools used: Scenarios Development, Experts Interviews and Back-casting.

Foresight as a tool for SD in natural resources: the case of mineral extraction in Afghanistan (2014)

As Afghanistan holds a great mineral wealth and is located in the vicinities of strong consumers (e.g. China and India), this paper explores how the country might realize its mineral potential avoiding resource curse risk. It analysed how it can be equitably distributed for an effective socio-economic development and prosperity. Foresight methodology was employed to better understand the possible futures and enable the provision of recommendations for policy makers.

Methods & tools used: Futures Triangle, Causal Layered Analysis, Scenarios.

Mining & Metals Scenarios to 2030 (2009)

The scenarios were constructed to stimulate dialogue, provide a multidisciplinary perspective and context for stakeholders to share their views as well as to provide tools for decision-makers and facilitate collaborative actions. Numerous workshops were held virtually and physically during 2009 for the process.

Methods & tools used: Scenarios development, STEEP, Brainstorming.

Vision 2040 – Global Scenarios for the Oil & Gas Industry (2014)
In the context of the pre-salt exploration, higher energy demand, increased costs of oil extraction the scenarios were constructed to pitch the technical and logistical challenges of the pre-salt exploration against global economic, social and geopolitical factors influencing the Oil & Gas industry and thereby answering what are the main uncertainties and trends and how will these influence the future and what are the implications of the different scenarios for the domestic (Brazilian) industry.

Methods & tools used: Scenarios Development

Alternative Scenarios for the North American Mining & Minerals Industry (2001)
As an identified disconnection between practices and values of today's society led to concerns over the Social License to Operate[14], the scenarios provided the means of assessing global mining & minerals in terms of transition to sustainable development, identifying how the services provided can be delivered in accordance with sustainable development and proposing key elements for an action plan. Additionally, it provided a platform for analysis and engagement of ongoing cooperation and networking between stakeholders. It pursued 5 tasks: i) profiling of the north American mining and minerals industry, ii) setting of practical principles, criteria or indicators to monitor individual operations in terms of sustainability and suggesting approaches for implementation, iii) outline specific actions and timelines for stakeholders to meet in moving forward towards sustainable development, iv) scenarios for identifying risks and opportunities, issues, challenges and areas of consensus and potential prescriptions for adjusting policy and practices, and v) synthesize and communicate the results.

Methods & tools used: Scenarios Development, Brainstorming, Experts Interview

Foresight Mining & Metallurgy Report (2000)
The South African National Research & Technology Foresight launched programme seeking to identify key areas and market opportunities for improving quality of life and wealth creation. It looked at various areas, including Mining & Metallurgy, identifying key strategic research and technology topics for the sectors that could realize its objectives over the next 10 to 20 years.

Methods & tools used: Scenario Development, SWOT, STEEP, Delphi.

Global Foresight and Roadmapping for the development of rare earth industry in Brazil (2014)
This paper emerges in the context of the Chinese monopoly on rare earths market and effects such as (Chinese) exports quota restrictions, higher prices, increasing demand and limited supply. It aimed at structuring a long- to medium-term agenda, linked with the development of REE productive application chains. The Foresight approach sought to support the formulation of a

[14] In the mining sector context, Social License to Operate refers to the level of acceptance or approval by local communities and stakeholders affected by mining companies and their operations.

technology and innovation policy for the development of the REI in Brazil, by anticipating market dynamics related to RE specific applications.

Methods & tools used: Scenarios Development, Brainstorming, Roadmapping, Experts Interview, Literature Review.

Polinares Project – Future world images and energy & minerals markets (2012)
In the context of a transition period, in which the share in international production, trade and finance of emerging markets is growing fast. Geopolitical impact of these countries is increasing, not only as a result of their growing soft power, but because of their increasing hard power. OECD countries are meanwhile experiencing a relative decline in terms of economic importance and geopolitical impact. Identify the main global challenges relating to competition for access to resources, and to propose new approaches to collaborative solutions – Reconnaissance of the future of geopolitical and geo-economic relations and the impact on energy and mineral market policies. The "Future World Images" was developed to recognize future of geopolitical and geo-economic relations and the impact on Energy and Mineral markets and policies. Done in 2 stages, near future, where path dependency exists and 4 storylines covering the post period to 2040.

Methods & tools used: Scenarios Development

Long-term future copper scenarios for exploration targeting strategies (2016)
Part of the project "Future of Mineral Exploration", which investigates long-term future of copper mining and guide exploration targeting strategies. Scenarios were constructed with the aim of developing the idea of 'multiple hypothetical reserves' using the Oxford Scenario Planning Approach. The publication is framed under the current consensus over the declining copper ore quality, with resource depletion paradigms determining views of long term future. Increase on general costs can be mitigated with new mineral discoveries. Struggle in scientific and economic techniques to incorporate the multiple external factors affecting the copper mining in the future provided the background for constructing scenarios considering the complex interaction of geological, socio-political, environmental, technological and other factors. It also compared each scenario with the 20 main copper projects to determine which deposits are the best proxies to guide exploration targeting.

Methods & tools used: Scenarios Development, SWOT.

Minerals4EU – Developments of the raw materials markets (2015)
On the influence of technological change and substitution on the demand for the non-energy raw materials. It explored how technological change influences the demand for raw materials and to illustrate how this can be taken into account when generating forward-looking raw materials intelligence, including scenarios for future demand. A particular focus is placed on so-called "technology metals".

Methods & tools used: Scenarios.

Recreate Project (ongoing)
As a primary goal, it aims at providing policy support to overcome the fragmentation of EU research area & create clear cut research agenda for climate action, resource efficiency & raw materials by drafting a vision of EU R&I policy related to these 3 focus areas for 2050 and describing 3 complementary views to reaching the vision. It seeks to provide an overview of emerging synergies and trade-offs between the focus areas, anticipate their development in alternative future scenarios and give recommendations for reaching a desired future state.

Methods & tools used: Trend Analyses, Delphi, Literature Review, Futures Triangle, STEEP.

Extract-IT (2013)
The project sought to define FET (Future and Emerging Technologies) research topics supporting the ICT challenges of mineral extraction under extreme geo-environmental conditions by identifying emerging and potentially disruptive trends in the use of ICT in future underground mining (timeframe 2050), convert these findings into call for proposals under H2020 future and emerging technologies programme.

Methods & tools used: Mind-mapping, Delphi Survey, Scenarios

POLFREE Project (2015)
It explored policy mixes for the transition towards a more resource efficient economy and investigated the 'web of constraints' on using natural resources efficiently, understand how a resource-efficient economy look like and what are the consequences if this is achieved or not.

Methods & tools used: Scenarios, Back-casting, Literature Review, SWOT.

Mining Scenarios for Colombia (2014)
Provide a national tool for the mining sector over strategic decisions and for the development of the national plan of mining development (UPME/Ministry of Mining) and recommendation of strategies that were planned, partially implemented or brand new.

Methods & tools used: Literature Review, Structural Analysis, World Café, Scenarios Development.

From Copper to Innovation: Mining technology roadmap 2035 (2016)
It was developed to generate consensus on the future outlook for mining on an internal copper sector level, identifying technological problems and challenges. On an external level it provides the information to stimulate collaborative research in the academic sector, technology institutes and among suppliers and consulting firms.

Methods & tools used: Technology roadmap.

Appendix B – MICA Stakeholders Classification – Raw Materials Intelligence

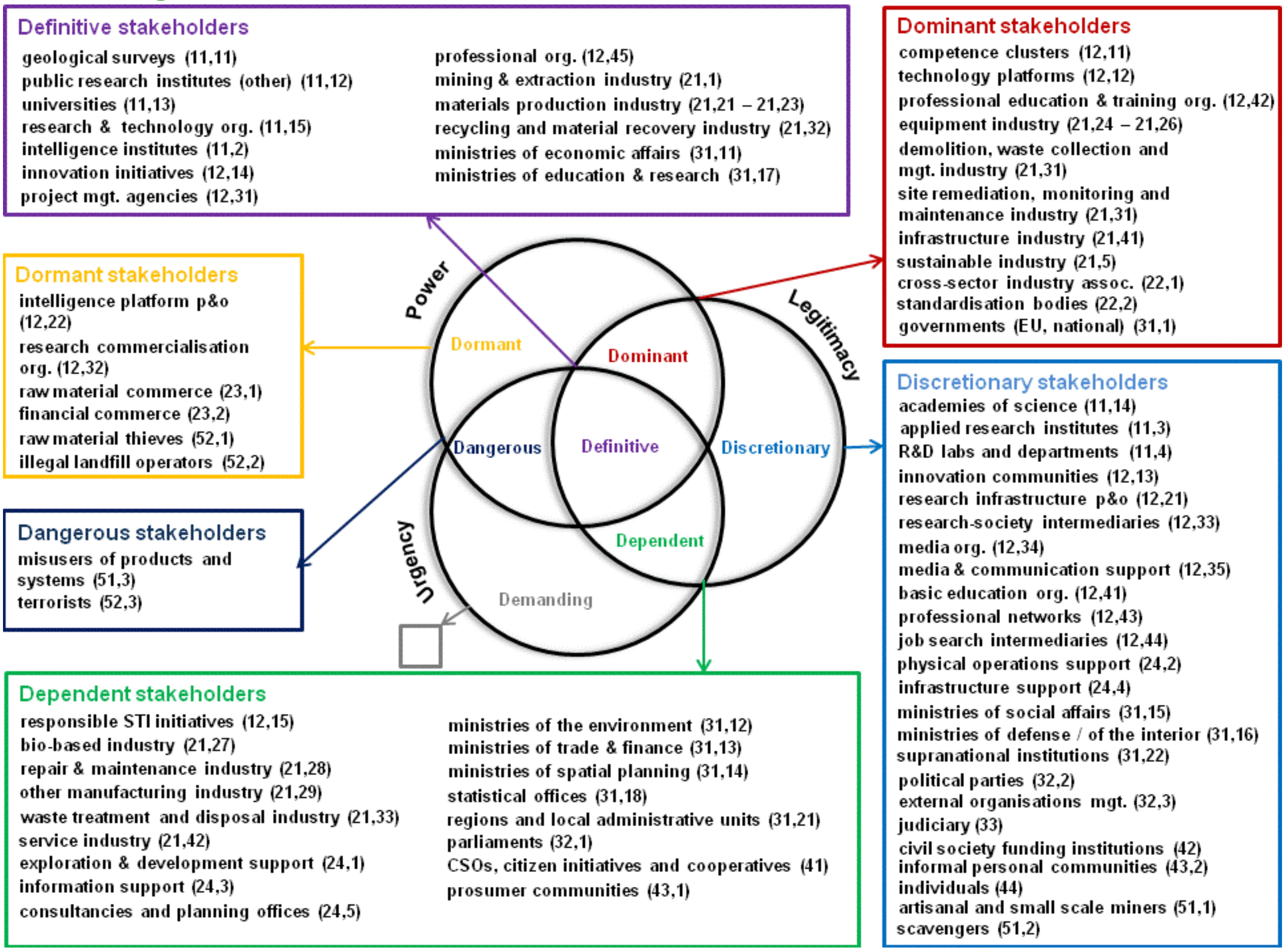

Figure 38 Assignment of 90 MICA stakeholder groups to 6 stakeholder types (Erdmann et al. *2016).*