# Updating scenarios

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# Updating scenarios: A multi-layer framework for structurally incorporating new information and uncertainties into scenarios

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A B S T R A C T

A dynamic and fast-changing environment brings challenges for generating long-term scenarios. Although the need to update scenarios for decision-making is recognized, a structured way for executing this process remains unclear. To configure a solution, we propose two concepts that need to be introduced: 1) that scenarios consist of a multi-layered structure, and 2) that changes should be classified according to their impact and uncertainty. Based on this classification, changes are incorporated into the different distinguished layers. To apply these concepts during an update, the paper presents a framework to structurally incorporate new information and uncertainties into scenarios, keeping them up-to-date while guaranteeing that the scenarios remain realistic and useful. The framework is applied to a test case consisting of three scenarios describing the European power market to illustrate how the framework performs in a practical context. Electric Vehicles are chosen as an uncertainty to illustrate how to structurally incorporate changes. Results show that using the framework allows the complexity of the update to be simplified into a step-by-step process. Additionally, it increases transparency by creating a common language for understanding *if* and *how* the changing external environment should be incorporated within scenarios.

## 1. Introduction

Scenarios are considered to be a valuable tool for dealing with future uncertainties and complexities (Amer, Daim, & Jetter, 2013; Chermack, Lynham, & Ruona, 2001). They do not try to predict the future nor are they a business plan, instead they provide well-grounded projections of the future that help understand how the world might develop and to imagine what the consequences of contemporary decisions are. As such, they are an essential foundation for today's policy strategies and investment choices.

A dynamic and fast-changing environment brings challenges for generating long-term future scenarios, as it hinders their plausibility and relevance. Outdated scenarios will result in pathways that are no longer realistic or achievable and therefore reduces their usefulness for making decisions. As some uncertainty is resolved over time, while other uncertainties arise, keeping track of changes is vital.

The need to 'update' scenarios to create meaningful insights for making decisions is clearly recognized within the literature (IEA,

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2014; Leggett, Pepper, & Swart, 1992; Van Vuuren & O'Neill, 2006; Van Vuuren et al., 2010). However, the challenge lies in execution. Keeping scenarios up to date requires a careful assessment of the impact and uncertainty of new developments. Should changes be incorporated by altering some components within a scenario? Does it require adapting storylines? Or does it challenge key underlying assumptions, necessitating new scenarios? Increases in the efficiency of solar PV panels, an increasing role of hydrogen or a breakthrough in nuclear fusion, would be examples in this regard. Moreover, while several studies discuss how new information and uncertainties are incorporated into scenarios, a clear and structured way for executing this complex process remains absent. Performing an update in an unstructured manner imposes multiple problems. First, the update becomes time-consuming as there is no standard way of executing the process, leading to inefficiencies. Second, as the process is often completed by multiple actors, an unstructured way of working imposes difficulty in communicating how and what changes are made, leading to a lack of traceability. As a result, the process may lack transparency, making it harder to understand the consequences of incorporating new elements into scenarios.

This paper proposes a new framework to structurally incorporate new information and uncertainties into scenarios, keeping them up-to-date, guaranteeing that the scenarios remain realistic and useful. It aims to make scenarios more dynamic by developing a step-by-step process that identifies different layers within scenarios, classifies changes according to their impact and uncertainty, and finally links those changes to each layer to identify what specifically requires updating. This allows for a more efficient and thorough way to update scenarios, keeping them plausible and relevant without the need to develop new scenarios from scratch.

This article proceeds as follows: Section 2 provides a literature study on how scenarios are currently kept up-to-date and why this is unsatisfactory. Section 3 addresses two gaps, highlighted by the literature study, by introducing two new concepts. Section 4 discusses the different steps that together form the proposed dynamic scenario framework. In Section 5 a test case illustrates how the framework should be applied in a practical context. This highlights the benefits of using such a framework, while at the same time uncovering its limitations. Section 6 elaborates on the main results of the test case. Section 7 offers a discussion, before providing conclusions and recommendations for further research in Section 8.

## 2. Updating scenarios

Despite scenario practice being used extensively for almost 50 years, there is a relative consensus on what scenarios are despite the existence of several definitions. Herman Kahn, seen as one of the founders of scenario generation, describes a scenario as "a set of hypothetical events set in the future constructed to clarify a possible chain of causal events as well as their decision points" (Kahn & Wiener, 1967, p. 6). Shell, known for its pioneering use of scenarios, defined a scenario as "a story that describes a possible future while it identifies some significant events, the main actors and their motivations, and it conveys how the world functions" (Shell International BV, 2008, p. 8). Generally, scenarios are portrayed as possible future situations and the stories of the paths that lead to those specific futures (Bishop, Hines, & Collins, 2007; Chermack et al., 2001; Cornelius, Van de Putte, & Romani, 2005).[1] Based on an extensive analysis of the term 'scenario' occurring in the literature, Spaniol and Rowland (2018) come to this comprehensive description: "scenarios primarily have a temporal property rooted in the future and reference external forces in that context; scenarios should also be possible and internally plausible while taking the proper form of a story or narrative description; scenarios seem to exist in sets and the scenarios that inhabit those sets are systematically prepared to co-exist as meaningfully different alternatives to one another".

Scenarios have the ability to stimulate strategic thinking by indicating future problems and help develop a macroscopic view of the environment you function in. They are often used for long-term planning, policy strategies or investment decisions, when the level of uncertainty is high and standard forecasting models are insufficient (Rigby & Bilodeau, 2007; Varum & Melo, 2010). They benefit in two main ways: 1) they let managers think about other possible futures than currently imagined, and 2) scenarios help to evaluate possible strategies under different future perspectives. To achieve the first goal, the process of generating storylines is the most important step. To reach the second goal, Chermack et al. (2001) argue that the stories that scenarios tell need to be transformed before they can be used for evaluating strategies. Where the former goal is about widening scope and accepting an uncertain and changing external environment (qualitative in nature), the latter is about making decisions about which area to focus on, increasing the amount of detail and reducing uncertainty (quantitative in nature).

The need to 'update' scenarios to create meaningful insights for making decisions is clearly recognized within literature (IEA, 2014; Leggett et al., 1992; Van Vuuren & O'Neill, 2006; Van Vuuren et al., 2010). Scenarios need to remain plausible and relevant if they are to produce feasible pathways that aid decision makers. Ensuring long-term future scenarios do not get outdated, however, is challenging in a dynamic and rapidly changing environment. While some uncertainties are resolved over time, new ones arise. It is imperative that such new developments are incorporated.

Despite the importance of keeping scenarios up-to-date, there is surprisingly little literature detailing how an update should be

[1] When it comes to scenarios, we focus here on the 2x2 scenario method within the intuitive logics school of scenario construction as the proposed framework is developed with 2x2 scenarios in mind. The intuitive logics school centers around developing scenarios through brainstorming sessions, stakeholder interviews and PESTEL analysis. It includes inductive and deductive scenario approaches, e.g. the Shell and 2x2 methods respectively. The 2x2 method involves the identification of factors or developments and ranking them according to importance and predictability, before selecting two critical uncertainties of which a 2x2 matrix is formed. The storyline of the scenarios is based on how these uncertainties are taken into account, which is described by the four different quadrants. The generated scenarios should all be equally plausible and therefore no probability to likelihood is assigned. For a more thorough discussion of types of scenarios, scenario methods, and scenario validity, please see Amer et al., 2013; Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006; Cardoso & Emes, 2014; Pillkahn, 2008; Van den Berg, 2019.

executed (Creutzig et al., 2017; IEA, 2014; Leggett et al., 1992; Van Vuuren & O'Neill, 2006; Van Vuuren et al., 2010). While several studies discuss how new information and uncertainties are incorporated into scenarios, i.e. how updates are performed, a methodological approach for executing this process is absent.

Schoemaker (1991) states that forecasts require to be updated frequently, while scenarios provide a general view for a longer period of time. "An Explorer's Guide" published by Shell International BV (2008), talks about reviewing generated scenarios over a period of a few years. They do not state how this should be done but highlight that if the assumptions on which the scenarios were generated have changed, new scenarios should be created. Nonetheless, no suggestion is provided for taking new information into account within already generated scenarios.

The International Energy Agency (IEA) recognizes the need to incorporate new information into their generated scenarios as they publish their World Energy Outlook (WEO) on a yearly basis, updating their previous version (IEA, n.d.-a). The IEA differentiates between political changes as some scenarios only incorporate formally adopted policies to create a baseline picture, the *"current policy scenario",* while the *"new policy scenario"* also incorporates policy proposals. The IEA (2014) discusses that to determine which policy proposals are included, case-by-case judgement is used. However, they offer no explanation for how this process is structured.

Van Vuuren et al. (2010) also clearly indicates the relevance of updating scenarios and has highlighted several points of attention when performing an update. A key takeaway is that the nature of a change is related to how it should be treated during an update. New information may simply require some parameters within the scenarios to be altered, while other information may challenge the *"original critical assumptions"* of the scenarios which require new scenarios to be generated. The difference is related to the speed of change regarding these variables. They argue to evaluate the long-term assumptions in these scenarios using appropriate long-term trends and should, therefore, not be influenced by short-term observations. Short-term changes may influence some components within the scenario while new long-term trends might question the relevance of the entire scenario. Van Vuuren and O'Neill (2006) also highlight the importance of maintaining the consistency of scenarios when new information is incorporated. However, besides indicating the relevance for evaluating scenarios and addressing ways to accurately do so, how to perform an update using the insights created is not described.

Hines and Bishop (2015) urge the importance of tracking indicators which helps to understand when the future is moving towards a certain direction and could help understand how this might impact business. They show the relevance of choosing indicators that are easy to understand and collect, and the importance of collecting reliable information on these changing indicators. The process of understanding how the future might change and the relevance of gathering information is recognized as important. However, the book lacks explanation on how the insight of changing indicators influences existing scenarios and how these changes might be incorporated in the existing scenarios.

Creutzig et al. (2017) critically examine the validity of scenarios using new information. Creutzig et al. (2017) thereby identify that the potential of solar energy has been systematically underestimated within energy scenarios. Indicating the underestimated growth of solar energy provides insight for updating this factor, however, changing this factor might also influence other components of the scenarios as they are highly interlinked. A weakness within this paper is the limited attention to the possible consequences of considering large changes to a single factor.

One of the most extensive descriptions of an update can be found in a paper by Leggett et al. (1992). In 1992, changing assumptions and new information that came available led the IPCC to request an update of their 1990 emission scenarios (Leggett et al., 1992). Leggett et al. (1992) discuss the performed update by highlighting how the assumptions on which the 1990 scenario are built, have changed and new uncertainties have emerged. Taking these changes into account, six scenarios were presented. Two of which represent a modification of the 1990 scenarios (IS92a and IS92b) and four scenarios considering new assumptions (IS92c-f). Leggett et al. (1992) extensively discuss what new information and assumptions are considered within the different scenarios. However, they make no attempt at addressing these changes nor why they are considered in a certain way. New uncertainties were translated into assumptions, but why some new uncertainties require a new scenario to be generated (and not new components within scenarios) is unclear.

This lack of a structured way to perform a scenario update imposes several problems. First, without a standard way of performing an update, the process is inefficient and time-consuming. Second, without a structured process, there are risks of miscommunication about how and which changes are made, especially if multiple people and departments are involved. Third, incorporating new elements into scenarios without the necessary transparency makes it difficult to fully comprehend their impact on existing elements.

We hence proceed by exploring a novel way for incorporating new information and uncertainties into scenarios. The literature study indicated three research gaps that this paper addresses. First, Van Vuuren et al. (2010) stress the importance of differentiating between parts within the scenario when performing an update. Small short-term changes might influence some components within the scenario while new long-term trends might require an entirely new scenario to be created. However, generally no distinction is made between layers within a scenario, and if so, their relationship with changes is unspecified. Second, the literature clearly makes a distinction between different types of changes and how they are considered within scenarios. However, it fails to define how to execute this assessment. Indeed, no method nor tool is found that assesses which changes need to be considered and why these are considered in a certain way. Third, there is no structured process for determining how new information and uncertainties should be incorporated into scenarios. Section 3 will address shortcomings 1 and 2, while Section 4 deals with the process.

## 3. Two concepts to aid the process

To configure a solution, two important concepts are proposed: 1) scenarios consist of a multi-layered structure, each layer having their own characteristics and 2) changes considered should be classified according to their impact and uncertainty to understand the nature of the change. Based on this classification, changes can be incorporated into the different layers to understand how each change influences the scenarios. A change refers to any event, whether political, technological, social or economic. Since only a few changes will alter the already developed scenarios, the impact and uncertainty matrix helps filter through these relevant changes versus those that are irrelevant and ought to be discarded. It also provides a means of categorizing each relevant change and helps understand what level of the scenario will be impacted and what amount of implementation effort is required.

As the ideas presented here are fundamental to the framework proposed, it requires an introduction on how these ideas were generated.

### 3.1. Multi-layered scenarios

The existence of different layers within a scenario is implicitly indicated by the fact that an update can be performed by altering some parameters within the scenarios without changing the high-level storylines (Van Vuuren et al., 2010). Additionally, this idea of a multi-layered structure is enhanced by the process of generating scenarios. Scenarios are built by formulating storylines that discuss possible futures while incorporating uncertainties. Before these qualitative scenarios are used for strategic decisions, several steps are executed to quantify these storylines (Bentham, 2014; Chermack et al., 2001; IPCC, 2005). The generation process of a qualitative scenario is about widening scope and accepting that the external environment is changing. Using these scenarios for strategic planning, on the other hand, is a process of making decisions on which areas to focus by increasing the amount of detail and reducing the level of uncertainty, and requires quantification. It is therefore concluded that within a scenario a more long-term macro perspective, qualitative in nature, and a more short-term focused (macro and micro) perspective, quantitative in nature, is present.

As part of the proposed solution, scenarios are divided into four distinct layers: *Framework, Storylines, Industry specific fundamentals* and *Numbers*. To define the characteristics of each layer, this research uses a socio-technical approach to transitions as a source of inspiration; the Multi-Level Perspective (MLP). The MLP of Geels (2002) is recognized as a useful framework and makes a distinction

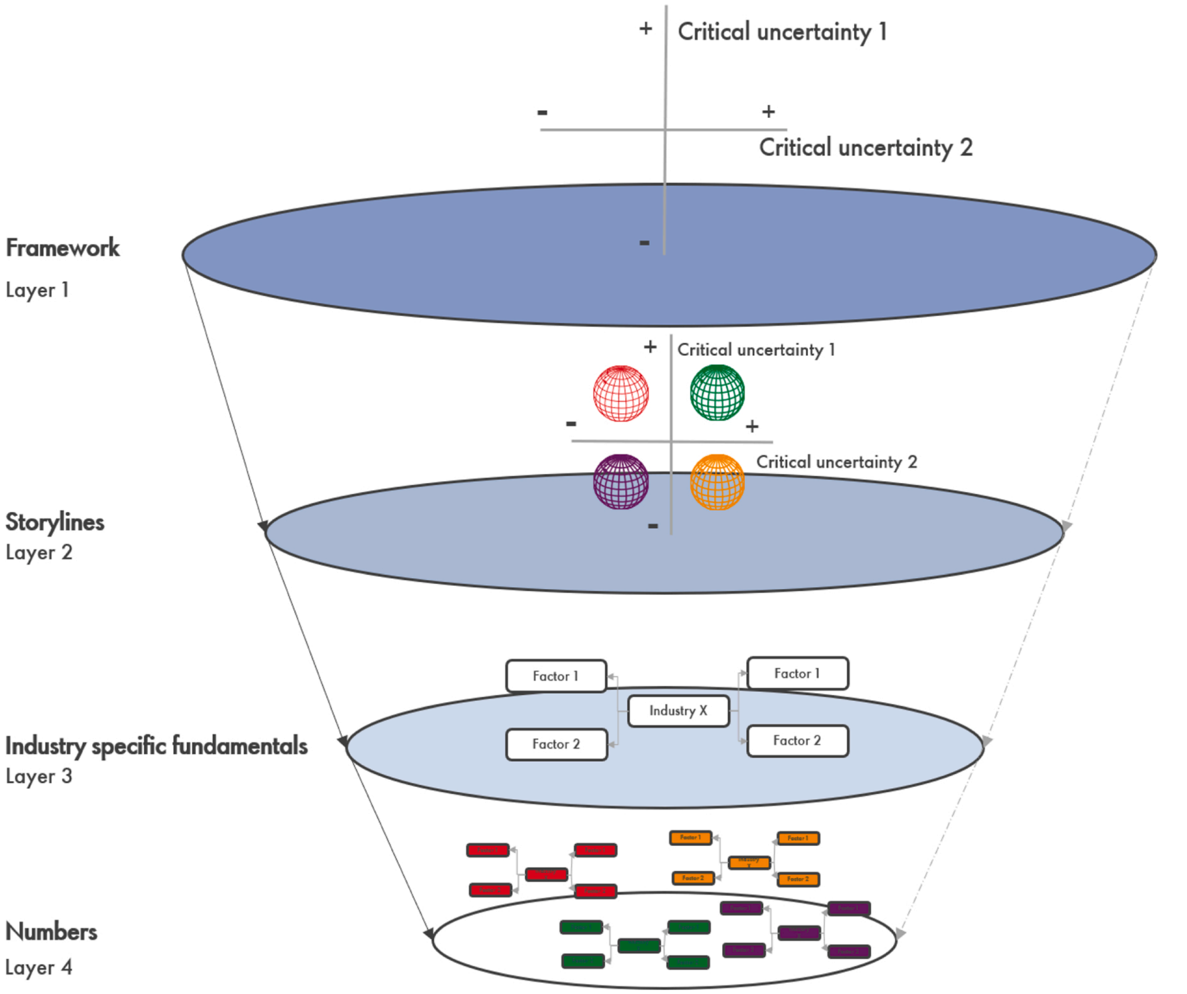



**Fig. 1.** Multi-layered structure within scenarios.

between different layers in society to indicate how society develops over time. It thereby acknowledges that external changes influence society at different levels. Additionally, it highlights the interdependencies within and between the different layers.

The proposed layers are shown in Fig. 1. Dividing scenarios into layers, being a novel idea, will be explained by discussing each layer. The numbering of the layers is done as such that it can be seen as a top-down structure, additionally because of the link to the impact uncertainty matrix (see Fig. 2).

It is important to note that assumptions are formulated within each layer. As over time some uncertainty is resolved and new uncertainties emerge, it is important to examine the validity of the assumptions with more recent data. Changes within assumptions indicate the need for an update. Proper indication of assumptions made in each layer is therefore essential.

#### 3.1.1. Layer 1 – framework

The first layer, *Framework,* forms the basis on which the scenarios are constructed. This layer represents the critical uncertainties affecting the business and provides the context in which the rest of the layers are formulated. These critical uncertainties are developments or problems that are long-term, highly uncertain and have a high impact on the business environment (e.g. degree of decarbonization, level of policy intervention). Indicating the extremes of these uncertainties on a 2 × 2 matrix creates the *Framework* (Fig. 1) and provides four different quadrants that form the basis for the qualified scenarios. This layer provides a long-term macro-perspective view and is therefore not subjected to rapid changes. Moreover, as this is the top layer, it is outside of the direct influence of the lower layers. Changes to this layer would require generating entirely new scenarios.

#### 3.1.2. Layer 2 – storylines

The second layer represents the *Storylines*, qualitative in nature, generated using the *Framework* defined in layer one. This layer discusses multiple perspectives on how the world might evolve in a qualitative way. The resulting set of scenarios all consider the same critical uncertainties, however this uncertainty unfolds differently within each scenario (Cardoso & Emes, 2014). As these qualitative scenarios discuss the world's evolution from the present to the end state indicated, other uncertainties, besides the chosen critical uncertainties, are considered (Van Vuuren & O'Neill, 2006). This layer defines in more detail how a world will look like if these critical uncertainties play out differently (e.g. high degree of decarbonization combined with high degree of policy intervention) thereby discussing the macro-perspective view of these future worlds in more detail but without being subjected to fast changes. This layer is highly influenced by the top layer without being directly influenced by the lower layers.

#### 3.1.3. Layer 3 – industry specific fundamentals

The third layer provides the building blocks for translating the qualitative scenario into a quantitative scenario. If we, quantitatively, want to indicate the future development of an industry, it is important to understand by which factors the industry is influenced. These often highly interdependent factors can be indicated by a flowchart showing the structure of this specific industry. This layer is subjected to relatively fast changes that influence how this market is structured (e.g. electric vehicles as a new technology gaining market share). Additionally, the interdependency between the different factors within the industry is important. Changes within one factor might influence other components and should be kept in mind when scenarios are altered (e.g. electric vehicles influencing electricity demand).

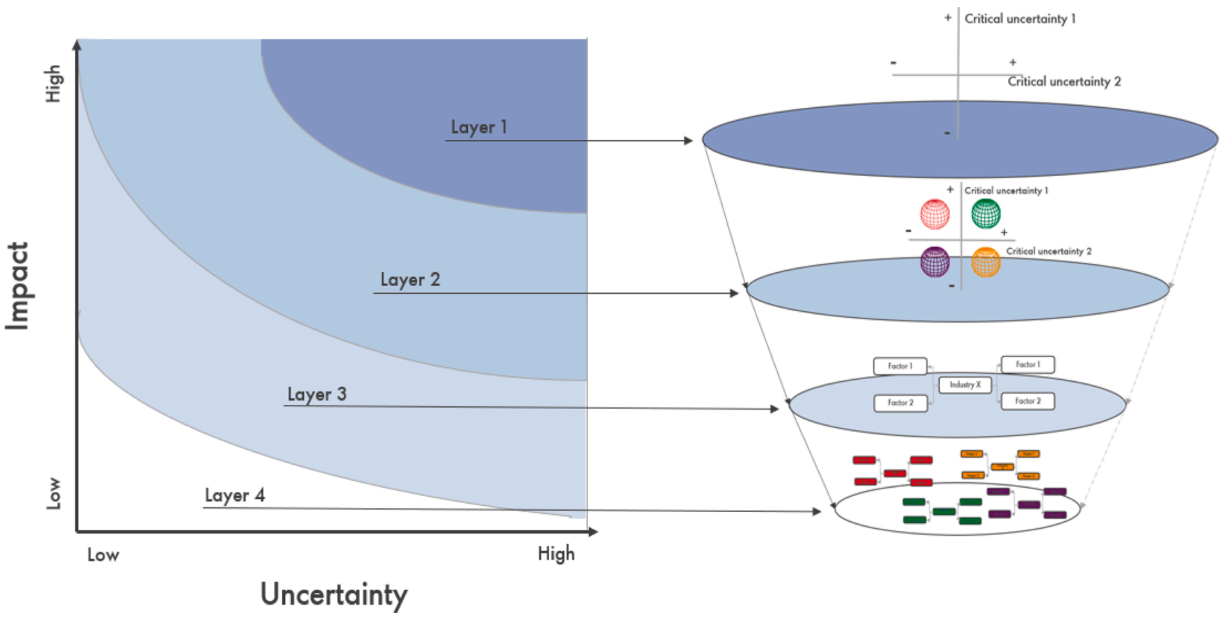



**Fig. 2.** Linking the impact-uncertainty matrix to the layers indicated within scenarios.

#### 3.1.4. Layer 4 – numbers

Within the fourth layer, *Numbers*, the qualitative scenarios are translated into quantitative scenarios using the *Industry specific fundamentals* indicated with layer three. External data is used to add numbers to the different factors indicated. For each individual scenario, these numbers should be altered based on the trends highlighted within this specific scenario. For example, a forecast of the percentage of electric vehicles in 2050 is 60 %. In a scenario with high pressure for decarbonization, this percentage is thought to be 75 %, while a scenario in which decarbonization is not a pressing topic this percentage could assume 40 %. It is especially important to indicate the sources of the data used for defining this layer as an update would require checking whether the numbers are still plausible and relevant. Recording these sources provides the opportunity to easily retrieve historical data, gather updated data from the same source and check if the decisions made are still valid.

Important to note is the interdependencies between the layers. Incorporating changes in higher layers would require changes in lower layers, while changing lower layers would not necessarily require changing higher layers.

There are multiple advantages of defining this multi-layered structure within scenarios. At first, it provides a common language for what a scenario constitutes. By acknowledging the differences within a single scenario and explicitly stating each layer, it provides a tool for communication. Secondly, indicating layers defines the current structure of the scenarios and provides a good overview to understand the relation between different components. It thereby increases the transparency of what a scenario is and reduces some of the complexity of these multifaceted scenarios. When incorporating changes, layers also help understand the consequences for the rest of the scenario.

### 3.2. Impact-uncertainty matrix linked to scenario levels

When incorporating the external environment into scenarios, the nature of the change will influence how scenarios are affected. Currently, no tool exists for understanding which changes affect the scenarios in what way, even though literature indicates that it is crucial for understanding future situations (Benedict, 2017; Pillkahn, 2008). A tool that is often used to classify changes as an input for generating scenarios is an adapted version of the matrix of Wilson (1983) using two dimensions; impact and uncertainty (Pillkahn, 2008). The impact refers to the current impact on the drivers of the organization or the current impact on the key factors of project success (Krueger, Casey, Donner, Kirsch, & Maack, 2001). The uncertainty is considered as: *"the level of variation in the range of possible evolutions of the driver itself"* (Speziale & Geneletti, 2014, p. 3). The impact-uncertainty matrix is normally used to identify critical uncertainties, high impact and high uncertainty, around which the scenarios are built (Pillkahn, 2008). Although the focus within this paper is on updating instead of generating scenarios, this research uses the impact and uncertainty level assigned to a change as a guideline to determine in which layer the change should be considered (Fig. 2). The matrix is constructed using two dimensions, namely Impact vs. Uncertainty. However, a third dimension such as time could be added to track the evolution of uncertainties and their impact on the scenarios over time, as highlighted by Geels (2002) and Krueger et al. (2001). This can help highlight certain trends and thus could change the categorization of the uncertainty. Nonetheless, for clarity and simplicity in describing the framework, the addition of a third dimension is not included here.

Assigning a certain impact and uncertainty to the changes in the external environment forces the scenario planners to structurally think about how these changes might impact the scenarios. It is the level of both impact and uncertainty that determines the layer in which a change should be incorporated. A change with highest impact and highest uncertainty should be incorporated within layer 1, while one with highest impact and lower uncertainty or highest uncertainty and lower impact should be placed in layer 2. A change with lower impact and lower uncertainty should be in layer 3 and a change with lowest impact and lowest uncertainty should be considered in layer 4. The different levels will be discussed in more detail below.

#### 3.2.1. Layer 1 – High impact & High uncertainty

Changes assigned with a high impact & high uncertainty are classified as critical uncertainties and therefore influence layer 1 (Framework). As these changes are found highly unpredictable and important, these critical uncertainties should be considered within all scenarios to a different extent and would therefore require new scenarios to be created.

#### 3.2.2. Layer 2 – Medium impact & High uncertainty || High impact & Medium-Low uncertainty

Changes classified with a Medium impact & High uncertainty or High impact & Medium-Low uncertainty need to be incorporated in the second layer (Storyline). These issues influence the qualitative scenarios, are not subjected to fast changes and should be incorporated differently to differentiate between scenario storylines. Changes with a medium impact but high uncertainty should be considered within some scenarios as they will not influence the entire business environment, while changes classified with low uncertainty, but a high impact should be incorporated within all Storylines as they are fairly certain and have a high impact on the business environment. However, within each scenario, the change is incorporated to a different extent.

#### 3.2.3. Layer 3 – Medium impact & Low uncertainty || Low impact & High uncertainty

Changes classified with a Medium impact & Low uncertainty or Medium/Low impact & High uncertainty need to be incorporated into layer 3 (Industry specific fundamentals) or closely monitored. As this layer provides the building block for translating the qualitative scenario into the quantitative scenario, changes with a medium impact and low uncertainty need to be considered within all scenarios (to a certain extent). Changes with a low impact but high uncertainty should be considered within one scenario or closely monitored as they do not have an immediate impact on the business environment but are highly unpredictable (Krueger et al., 2001).

#### 3.2.4. Layer 4 – Low impact & Low uncertainty || (very) Low impact & High uncertainty

Changes classified with Low impact & Low uncertainty or (very) Low impact & High uncertainty need to be closely monitored or not considered at all. It is important to note, that although new changes classified in layer four are not considered during an update, layer four can change. If changes in higher layers are incorporated, layer four will also change. Additionally, if during an update it is noted that the assumptions within layer four have changed, these also need to be altered.

## 4. Dynamic scenario framework

To apply the concepts introduced during an update, several steps need to be performed. This section discusses the different steps that together form the proposed methodological framework and attempts to close the gap within literature by offering a structured process for incorporating the changing environment into scenarios; a topic that is currently under-explored. Fig. 3 presents the entire process consisting of 7 steps. The first two steps are performed to understand the current scenarios and their buildup. The third step is executed to understand the changing external environment and provides the required input for performing an update. The 4th step is the first part of incorporating the external environment into scenarios by adjusting the assumptions in layer 4, referred to as a "regular update". Within step 5 and 6, new trends and uncertainties, not yet considered within the scenarios, are dealt with by determining *if* and *how* these should be considered within the scenarios. Lastly, the changes are validated in step 7. Each step is briefly discussed below.

### 4.1. Step 1

The first step within the framework is to define the boundary of the scenarios. Defining the scenario boundary is done by discussing the scope and focus area within the scenarios. The scope can refer to a geographical location and timeframe, while the focus area is related to what is found important within the scenarios. Additionally, the objective of defining the scenarios should be highlighted. This helps to keep focus when performing an update. Moreover, by repeating the goal it justifies certain choices made during the update.

### 4.2. Step 2

The second step within the framework is to define the scenario layers. The structure of the current scenarios should be identified before performing any alterations. Each layer should be individually formulated to indicate their characteristics. Additionally, it is important to highlight the interdependency within and between the layers. An input of this layer is the current set of scenarios. Identifying the different layers within the scenarios before performing any alterations provides the basis of being able to structurally perform an update as this structure influences how changes should be incorporated.

Important to note is that steps 1 and 2 are executed when the framework is used for the first time. Once the boundary and the different layers have been defined, the same ones can be used for multiple updates.

### 4.3. Step 3

When performing an update, new information and uncertainties are considered. The main goal of retrieving this information is to understand the changes within the environment and the impact of these changes on the scenarios. Additionally, it provides the input for executing this update. The third step consists of two parts: 1) gathering information on assumptions made within the scenarios and 2) gathering information on new uncertainties not yet considered within the scenarios.

When the information is gathered on existing assumptions within the scenarios it should be evaluated whether the assumptions can be updated using a regular update (step 4) or the impact-uncertainty matrix is needed, indicating a new trend (steps 5 and 6). Evaluation of the relevant assumptions should start at layer 4 as this layer is subjected to rapid changes and the assumptions within this layer are most likely to change, while the assumptions in higher layers can still be valid. In most cases, changes made at a lower layer

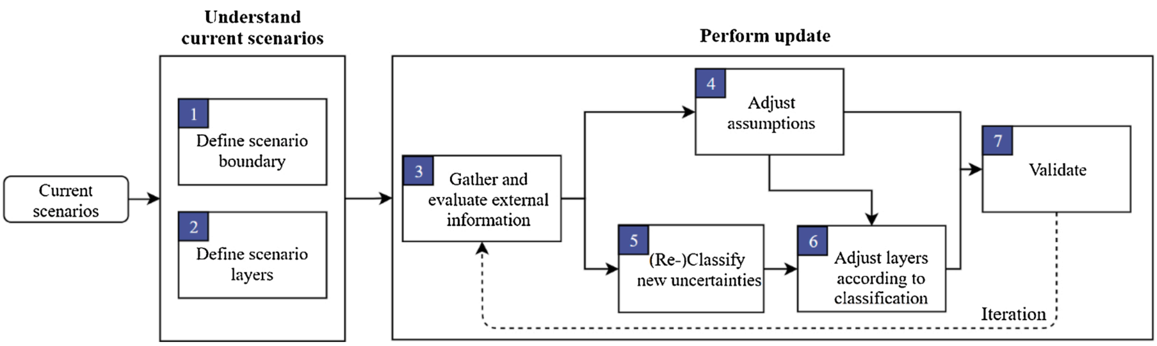



**Fig. 3.** Dynamic scenario framework.

will not necessarily impact any of the layers above. If this update is performed after a short period of time (couple of years), the second layer may not need any alteration as this layer discusses the more long-term macro perspective. Nonetheless, if a lower layer is often being updated, this might highlight a possible new trend that is currently being ignored at a higher layer. Re-evaluating the assumptions within higher layers may then be needed to capture this trend and steps 5 and 6 must be taken. This, therefore, requires the uncertainty to be re-classified onto the impact-uncertainty matrix and re-evaluate all the assumptions made related to this uncertainty.

New uncertainties, not yet incorporated within the scenarios, always require the use of the impact-uncertainty matrix (steps 5 and 6) and, therefore, do not require any further analysis here.

### 4.4. Step 4

Within step 4, external information is considered within the scenarios by adjusting the assumptions in layer 4, thereby performing the first part of the actual update, referred to as a regular update. Updating the current assumptions within the scenarios makes sure the basis of the scenarios are relevant and plausible before incorporating new uncertainties. The previous steps prepare this process to be executed in a structured way.

### 4.5. Step 5

As the external environment changes, new uncertainties not yet considered within the scenarios, may have arisen. Within this step, the impact-uncertainty matrix is used to evaluate if and how these uncertainties must be considered. Additionally, if a historical update was already performed using the impact-uncertainty matrix, it is worth checking whether the uncertainties classified then still have the same level of impact and uncertainty. Uncertainties not found relevant during the last update might have evolved and become more relevant, similarly, some relevant uncertainties might have become less relevant. Classifying these changes forces the scenario planners to think about their impact and uncertainty and their possible influence on the business environment. It guarantees that the right problems are addressed in the right way (in the eye of the scenario planners). The classification justifies why uncertainties are considered in a specific layer and thereby allows for easy communication.

Important to note is that the impact-uncertainty matrix provides a suggestion into which layer these uncertainties must be considered and different experts may have differing views. This is discussed in Section 7.

### 4.6. Step 6

Step 6 performs the second phase of incorporating the external environment into the scenarios to ensure they resemble plausible and relevant future visions by adjusting the layers according to the new trends and uncertainties found. By executing the update starting at the first layer, it reminds the scenario planners of the interdependency between and within the different layers and makes sure this interdependency is considered. Subsequently, by executing this step, the scenario planners are reminded that besides executing a regular update by checking assumptions within the current scenarios, new uncertainties might have evolved and are important to incorporate.

### 4.7. Step 7

Performing an update changes the scenarios, content-wise and relative from each other. Step 7 involves validating the changes made such that the scenarios represent a plausible relevant future and shows consistency within and between the scenarios. If after performing an update, the scenarios represent a slightly different version of the same story, the scenarios need additional changes to ensure unique and diverging scenarios. As these validation methods are often organization-specific, this research does not go into detail how this should be executed. If during validation, the validation criteria are not met, iteration is needed. This indicates that the scenarios need to be altered until the validation criteria are met.

## 5. Test case – scenarios on the future of transport

Thus far, this paper has argued the need for a framework that helps incorporate the external environment into scenarios. The objective of this test case is to translate the theory into a practical example and guide the reader through each step to clearly explain how the framework is intended to be used. As previously mentioned, the update process consists of both the regular update (step 4) and the update of new information (steps 5 and 6). Given that research on the latter is limited and there is currently no methodology in the literature that provides a structured process for incorporating new trends and uncertainties into scenarios, the presented test case focuses only on this novel aspect of the framework, namely the update of new information. Consequently, the processes for generating new scenarios and for performing a regular update will not be described here. Readers interested in performing these steps are referred to “An Explorer’s Guide” published by Shell International BV (2008).

The test case presents electric vehicle (EVs) integration as an example of a new technology that could potentially disrupt demand for electricity. The graph in Fig. 4 shown below highlights that long-term EV outlooks can differ significantly depending on views and sources (BloombergNEF, 2019a, 2019b). However, more importantly, we notice that these outlooks are consistently revised (generally upwards) each year, suggesting a trend.

As a large portion of the global vehicle fleet is expected to become electric, EVs could have a large impact on the global electricity consumption and should therefore be taken into account within the scenarios (BloombergNEF, 2019a, 2019b). The proposed framework is used to describe how new information related to EV adoption that has come available should be included into the scenarios. First, each scenario outline is presented (steps 1 and 2). Step 3 discusses the retrieved information regarding EV outlooks and their impact on electricity demand. As step 4 involves performing a regular update, this step is only briefly described, while the main focus will be on steps 5 and 6 that describe how to include this new uncertainty into our scenarios. The test case is finalized by discussing step 7. Readers interested in performing these steps in more detail are referred to "Framework for updating scenarios" (Van den Berg, 2019).

### *5.1. Understanding current scenarios (steps 1 and 2)*

#### *5.1.1. Step 1 - defining scenario boundaries*

In this test case, three scenarios, Base case, Factory and Rocket, are considered. Each describing a plausible unique pathway of the electricity market in Europe to 2040. *Base case* represents a central view on the evolution of EVs, in line with current trends and can be considered as a reference scenario. This could, for example, be represented by OPEC 2018 in Fig. 4. *Rocket* is a world in which decarbonization takes precedence and is pursued across all sectors through a diversified mix of low-carbon generation, reaching the targets of the Paris agreement, and assumes high EV adoption, represented for instance by BNEF 2019 in Fig. 4. *Factory* is a world with low policy intervention and very little focus on decarbonization resulting in a low EV adoption case, represented for instance by Exxon 2018 in Fig. 4.

#### *5.1.2. Step 2 - define scenario layers*

Before performing any alterations, the structure of the current scenarios should be identified; this is done by defining the four different layers.

*5.1.2.1. Layer 1.* The two critical uncertainties defined at the time the scenarios were designed were the *level of decarbonization* and the *level of policy intervention* – these are used to define the axes for Layer 1: Framework (See axes of matrix in Fig. 5).

*5.1.2.2. Layer 2.* This layer defines in more detail where each scenario fits on this matrix and focuses on the macro-perspective view of these future worlds. Each scenario is classified in terms of its degree of decarbonization (high vs. low) and level of policy intervention (active vs. minimal) – as shown in the matrix in Fig. 5.

*5.1.2.3. Layer 3.* This layer discusses the factors that influence the electricity market and their interrelations. For sake of simplicity, we will only consider the electrification of the transport sector since our critical driver is EV adoption. Figure A in the Appendix shows an example flowchart, describing the interrelations between the different parameters used.

*5.1.2.4. Layer 4.* This layer represents the numbers related to each scenario and is therefore the most detailed layer. Due to the extended amount of numbers related to these scenarios, they are not shown here. Readers interested in more detail are referred to (BloombergNEF, 2019a, 2019b).

#### *5.1.3. Step 3 – gather and evaluate external information*

As these scenarios were generated several years ago, new uncertainties and new information have since arisen and have become

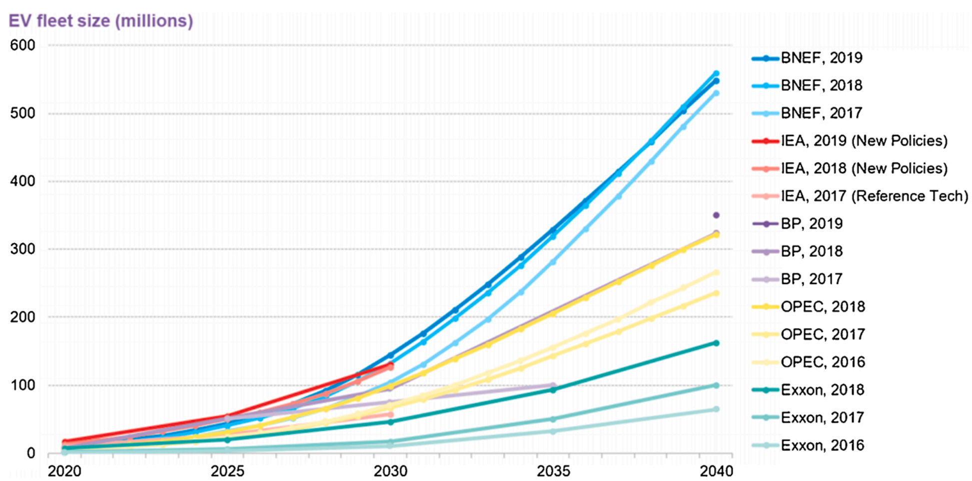



**Fig. 4.** EV outlook overview by different organizations (BloombergNEF, 2019a, 2019b).

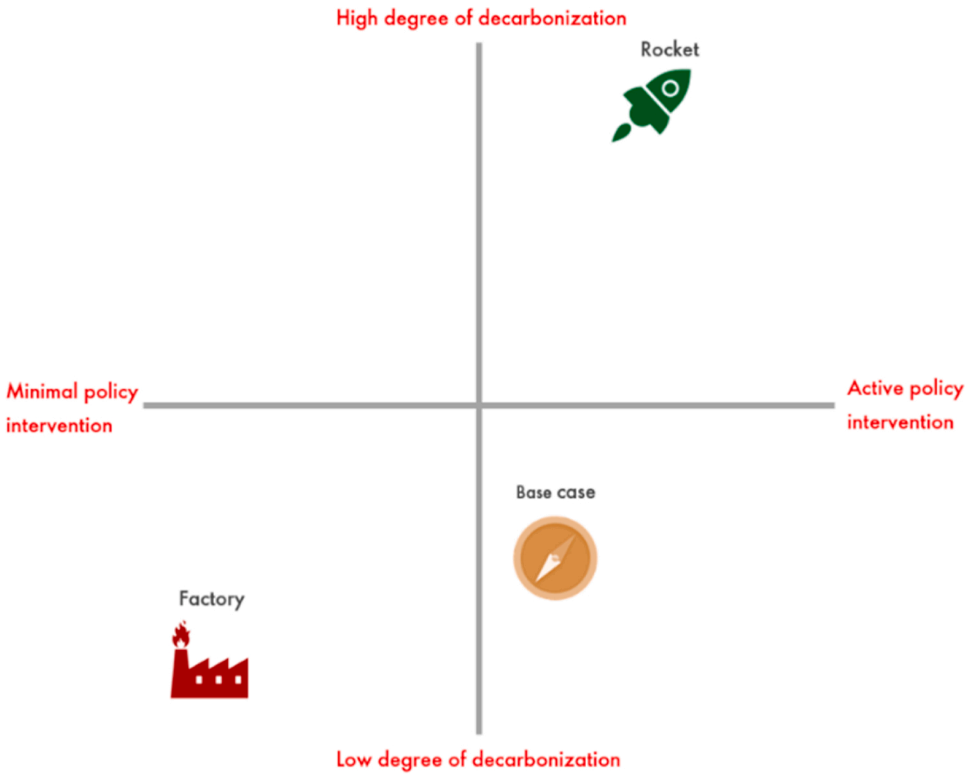



**Fig. 5.** Scenarios plotted onto framework.

available. After gathering information (both external and internal), a review of assumptions within the scenarios is recommended. This review determines whether assumptions today differ from previously assumed. If there are no changes in the information on which the assumptions are made, only changes within the lowest layer, layer 4, are performed - this relates to performing a regular update (step 4). On the other hand, if the basis on which the assumptions were made have changed, then higher layers may need adjusting. In this case, highlighted trends should be taken into account in higher layers, and may even change the scenarios and their storylines (step 5 and 6).

As can be seen in Fig. 4, the EV outlook is consistently revised upwards which might indicate a trend. Therefore, after reviewing the information retrieved it was concluded that this uncertain driver should be adjusted in step 4 and we will also follow steps 5 and 6. This means that not only layer 4 will be adjusted but also layer 3 and potentially layer 2.

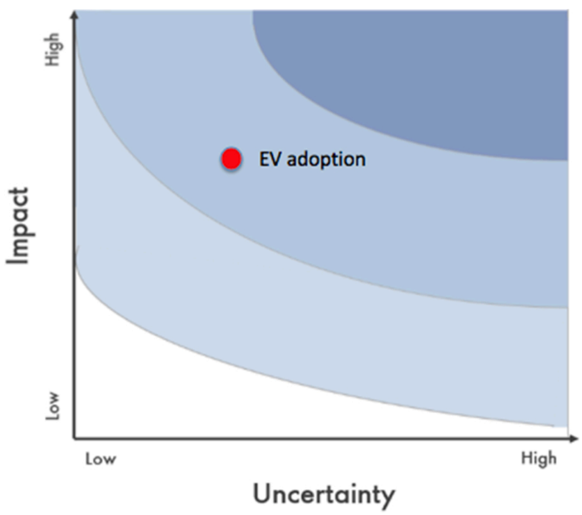



**Fig. 6.** Matrix with EV adoption classified.

#### 5.1.4. Step 4 – adjust assumptions

Many different assumptions should be tested and adjusted here, even if no trend is found. However, since our focus is on the novel element of this framework, in particular when a trend is found, the step of adjusting assumptions is not executed here.

#### 5.1.5. Step 5 – classify new uncertainties

To determine *how* EV adoption should be incorporated within the scenarios discussed, multiple experts were asked for their opinion on the level of uncertainty and potential impact of EVs on electricity demand. While the impact of EVs on the electricity market can be relatively high, there is a trend of faster and greater EV uptake. The uncertainty was finally classified as low-medium, while the impact was estimated as medium-high, resulting in EVs being classified within layer 2. The purpose of taking EV's into account within the different scenarios is to discover multiple pathways EVs could take to deal with this uncertainty. The classification of EV's on the impact/uncertainty matrix is presented in Fig. 6.

#### 5.1.6. Step 6 – adjusting layers according to classification

*5.1.6.1. Adjusting layer 2.* Classified within the second layer results in changing the storylines. As EV adoption is only a small part of the entire storyline, the part discussing the EV uptake should be adjusted. Each scenario should now consider a faster and greater uptake of EVs. These storylines are constructed using the external information retrieved and fitted into the worlds the scenarios represent. Additionally, multiple scenario-specific assumptions should be formulated based on the adjusted storylines. This process is not discussed here since this case study is not exhaustive but merely designed to highlight how this framework is useful to structurally update scenarios.

*5.1.6.2. Adjusting layer 3.* As EV adoption is considered within the second layer, it also influences layer 3. Updating the third layer entails creating a map of the different factors and data considered in the flowchart and their interdependencies with EVs. In other words, any factor influenced by a change in EV assumption will also need changing by considering the consequences this would have on other assumptions, for instance, greater EV adoption would lead to greater demand for electricity, resulting in a greater need for generation capacity to supply this demand. In a "green" scenario this will result in more renewables and potentially more regulation. In other scenarios this might result in more use of fossil fuels. As the flowchart indicates the interconnections of all factors in each scenario, alterations to one factor clearly shows the influence on the other factors.

The flowchart mapping the many factors and their relationship and interdependencies in Step 2 helps visualize these interdependencies and allows to selectively adjust the assumptions and variables affected by the change in EV assumption in a relatively simple manner. Within an entire update each factor should be individually checked and adjusted based on the altered view of each assumption.

*5.1.6.3. Adjusting layer 4.* The question to what extent EVs influence the factors identified in layer 3 is discussed in layer 4. Within layer 4 we quantitatively define the impact of EVs between the scenarios to mitigate its uncertainty. Each factor on which EVs have an influence should be defined with numbers using the external information retrieved with the formulated storylines as basis. To use the above-described example, the EV outlook in Rocket might translate into a 100 % increase in renewable capacity by 2050, while Factory might assume only a 5% increase. The outcome of adjusting layer 4 provides us with a scenario-specific alteration of the numbers. During a real update every factor should be closely examined also taking into account the interdependencies between factors as changing one factor might influence other factors as well.

#### 5.1.7. Step 7 – validation

Step 7 involves validating the changes made such that the scenarios still represent a plausible relevant future and shows consistency within and between the scenarios. There are multiple different methods to check the validity of the scenarios. As these validation methods are often organization-specific, some methods are briefly discussed to give a general idea of how this step might look like:

1) *Plot the scenario onto the Framework.* As each scenario should provide a distinct possible view of the future. Plotting the scenario again onto the *Framework*, after an update is performed, shows how the scenarios differ from each other regarding the critical uncertainties. If they have moved "too close" to each other, a scenario might need to be disregarded and a new scenario may need to be created. However, the meaning of "too close" is subjective and is determined by the scenario planners.
2) *Checking consistency between layers.* After performing alterations within the third or fourth layer, they should still represent the higher layers accurately. During each update the fourth layer will change, however, executing this process multiple times might change the fourth layer significantly over time. Therefore, one should check during every update whether the higher layers still represent the view in the lower layers or if alterations in higher layers are needed.
3) *Run model.* If the scenarios form the input parameters of a model, then running the model will provide insights into how the input parameters play out. This could highlight specific unrealistic situations. If this is the case, additional alterations might be needed.

## 6. Results

The results discuss how successful the framework is in structurally incorporating new information and uncertainties into scenarios by judging the process of executing the test case. It was argued that a structured process would increase time-efficiency, provide a common language for incorporating changes and would make the process more transparent. Additionally, it would significantly reduce some of the complexity of the process. Focus is, therefore, placed on these criteria to evaluate the process. Moreover, the test case was validated by multiple experts, within Shell and the academic world, who have themselves executed multiple scenario updates and were asked if there was any added value for them to use such a framework.

### *6.1. Overall benefits*

1 Easy to understand interdependencies within and between the scenarios

During an update, it is important to understand the interdependencies within and between the scenarios. By defining separate layers, it does not only become apparent what the differences and similarities between the scenarios are but also what the structure is within a single scenario. This reminds the scenario planners of the importance of these interdependencies; if one factor changes, other factors might also need changing. In addition, splitting the scenario into separate layers allows making changes only to the specific layer in which the change is needed, this hence focuses the effort only where it is due and avoids having to re-generate a complete scenario.

2 Use of impact-uncertainty matrix provides a useful visualization and discussion tool

The use of the impact-uncertainty matrix and its link to the different scenarios, provides a good structure to solve a difficult question: what is the influence of these uncertainties on the scenarios? The link provides a structure in understanding how these changes might influence the scenarios, therefore reducing some of the complexity of the process. More importantly, it creates a graphical means of translating qualitative, and in many cases subjective, information into a common classification. Even though subjective views may differ in terms of an uncertainty's degree of impact and level of uncertainty, it creates a platform for discussion and helps convergence towards a common view.

3 More time-efficient

Using the framework proposed helps reduce the time spent on discussing *if* and *how* changes should be incorporated. For each change it is decided if a regular update suffices or if the impact-uncertainty matrix is needed. Additionally, using this framework, it is immediately clear which other factors might be influenced when changing one factor. The flowchart especially provides a good overview of which factors to focus on, without the need to review all factors. Subsequently, as some changes are suggested to be incorporated within the lower layers, it saves time reviewing the entire scenario.

4 Reduces the complexity of the process

By providing a step-by-step process of performing an update, the complexity of such a process is reduced. As the complexity of performing an update is high, standardization is preferred as it allows the user to structurally think how to consider changes, thereby reducing possible failures. Moreover, using the framework, updating the scenarios can be divided into multiple smaller steps while maintaining overview.

5 Increases transparency

One of the main results is that the framework increases the transparency of the updating process. Scenarios are formulated to understand the uncertainty surrounding the future and use these insights for strategic decisions. As the people updating and formulating scenarios are often different from the ones making decisions from its outcome, communicating how and what changes were made is important. The framework has created a common language for incorporating new information and uncertainty, and makes the process easy to understand, simple and logical, thereby, improving communication. It was easy to explain which steps had been performed and why certain choices were made using the tools described. Using the framework, the updating process becomes explainable and transparent. The framework therefore not only reduces some of the complexity of the update but also increases the transparency, thereby, making it easier to communicate to people who have not participated in updating these scenarios.

### *6.2. Overall improvement points*

1 Classifying changes onto impact-uncertainty matrix

When classifying changes onto the impact-uncertainty matrix, it was shown that the opinions of the experts were not uniform. The classification represents the importance of a subject in the eye of these scenarios planners and is therefore subjected to opinion. Assigning a certain level of impact and uncertainty might therefore be difficult.

2 Acquiring information is time-consuming

An important step within the framework is to retrieve information about external developments. Retrieving this information was very time-consuming and sometimes difficult. Due to the abundance of information, it might be difficult to understand what information is important and what is not.

3 Lack of information to use framework

Additionally, when scenarios are generated, it is often not registered which sources are used to formulate the different assumptions. Formulating the layers might then be difficult due to the lack of information on how certain conclusions were drawn. It was therefore a difficult and time-consuming process to visualize and describe the different layers. However, this also stresses the need for such a structure.

## 7. Discussion

The literature clearly distinguishes different ways in which changes are considered in and processed into scenarios. It fails, however, to address how they execute this assessment. This research gap was addressed by proposing to use the impact-uncertainty matrix to classify changes and the step-by-step process. However, there are several considerations and implications to keep in mind:

(1) *How an update is performed is highly dependent on how one categorizes uncertainties within the impact-uncertainty matrix.* Depending on the views of the people classifying the uncertainties, the resulting update could be performed differently. One could argue using this tool, highly influences how an update is performed. The question however is whether this should be considered a limitation. An update will always be influenced by the views and opinions of the persons involved, regardless of whether the impact-uncertainty matrix is used or not. While the matrix provides a tool to structurally translate these views, it does not provide a means to reach consensus in the way uncertainties should be classified and hence how an update should be performed. For such consensus-building, additional approaches may be used (Innes & Booher, 1999).

(2) *Difficult to assign a certain level of impact and uncertainty*. Following point one, the opinions on the level of impact and uncertainty assigned to an issue may not be uniform. It is important to note that a perfect prediction of the amount of impact and uncertainty would mean to foresee the future and therefore that is not possible. However, it may be important to indicate some criteria to help steer the discussion. For example, if the size of the market on which the uncertainty has an impact is small, the impact on the entire industry might also be small.

(3) *Adding a third dimension to the matrix.* The addition of a third dimension such as time would allow tracking and visualizing the evolution of uncertainties over time as well as their impact on the scenarios. This could highlight certain trends and change the position of an uncertainty on the matrix. If a certain trend shows a strong path of becoming more (or less) impactful it might be important to increase (or decrease) the attention towards this change and execute additional (or less) analysis.

(4) *The layers defined in this paper may not always be fully separable.* For example, changes in technology characteristics (layer 4), may be so large that they lead to disruptive changes in an industry (layer 3). It is important to be aware of such ambiguities when applying the method (see also Step 6 of the method described here).

(5) *The validity of one-to-one link with scenario layers.* Within this research, a one-to-one link is suggested from the impact-uncertainty matrix to indicate in which layers the issues need to be considered. The question might arise if this one-to-one link is always valid. This link was made based on literature (Krueger et al., 2001; Van Vuuren et al., 2010) and the characteristics of the layers defined (Geels, 2002). The lines within the matrix provide a *suggestion* onto which layer the changes need to be incorporated and should not be seen as conclusive. It provides a tool to structurally think on how the uncertainties impact scenarios. It might happen that scenario planners classify an uncertainty using the matrix and not agree on what is the appropriate layer. Many articles indicate the use of the impact-uncertainty matrix to identify critical uncertainties, however, they rarely mention how this uncertainty and impact needs to be assigned (Benedict, 2017; Quiceno et al., 2019; WSP, 2018). Pillkahn (2008), therefore, rightfully argues there is a lack of suitable criteria for identifying differences between changes. During the test case, such a situation has not occurred, and it has provided a good tool to translate the opinions surrounding an uncertainty into a suggestion *if* and *how* they should be considered within the scenarios.

(6) *Performing the update.* Another point that requires attention is the fact that the process of performing an update, using the framework, is still very open. The framework is used to guide the process of keeping scenarios up-to-date and to make the choices in this process more explicit, but the updating itself completely depends on the persons executing the update.

(7) *The framework proposed is brought forward by the authors as a proposal to improve scenario updating processes.* We do not claim this is the definitive procedure for updating scenarios and it is not suggested that the framework presented is the only “right” methodological approach possible. It should be seen as a tool to help structure the complex process of updating scenarios, thereby, reduce some of its complexity. This paper was developed with 2 × 2 scenarios in mind that fall within one specific school of thought, i.e. intuitive logics. The developed framework might be applicable to other scenario approaches as well, but this would require further investigation. We believe that the sequence of seven steps, set out in Section 4, is likely to be broadly applicable to many scenario approaches as it deals with elements that are quite common in scenario building.

## 8. Conclusion & future work

To structurally incorporate new information and uncertainties into scenarios, keeping them up-to-date, and ensuring that the scenarios remain realistic and useful, a framework consisting of 7 steps is developed. The framework aims to offer the user a tool that helps him/her to think about *if* and *how* changes should be incorporated within scenarios and what the impact of these changes are for the rest of their scenario.

Using the framework allows the complexity of the update to be simplified in a step-by-step process. For each change it is decided if a regular update suffices or if the impact-uncertainty matrix should be used to understand *if* and *how* they should be considered within the scenarios. By separating the update in smaller concrete steps, understanding how these steps influence the rest of the scenario, a major part of the complexity is reduced. Subsequently, when using the framework, the process becomes increasingly transparent. Increasing the transparency of the process increases understanding of the scenarios itself and changes made, thereby, making the process explainable and justifiable, on why and how choices are made. The framework proposed does not only increase the transparency of keeping the scenarios plausible and relevant for the scenario planners, but also creates a language for communicating it to a broader audience. Scenarios are constructed to understand the uncertainty in model structure and model parameters as a basis for making decisions. The layers proposed trigger modellers to think differently about scenarios, taking a step back from the complex components and creating an overview of their main purpose and views discussed. This also could help a broader group of stakeholders to better understand the scenarios and their outcomes, thereby creating a broader understanding.

An important advantage of using the framework presented here is that it makes the choices in scenario updating transparent. This has substantial advantages for the teams working on scenario construction. However, the value would be enhanced even further if the use of the framework for each update round was shared with the people who have not participated in updating the scenarios - this would allow them to understand the choices that were made and to interpret the progress made in scenario development. As the framework applies primarily to updating new information rather than generating new scenarios, and hence changes are made to layers 3 and/or 4, the participative process of creating new scenarios would not need updating. However, if following the framework, it is deemed that new scenarios need to be generated as a result of changes in layers 1 and/or 2, then the participative process may need updating.

The work presented within this paper has fulfilled the research aims which were initially defined. However, due to the research findings and the indicated limitation, several questions have arisen and remain to be answered. Therefore, there are some areas in which further research is recommended to further develop the framework:

As highlighted in the discussion, classifying a change onto the impact-uncertainty matrix is subjected to opinion. Further research could focus on formulating criteria to help steer discussion. This could move forward discussion surrounding many different opinions.

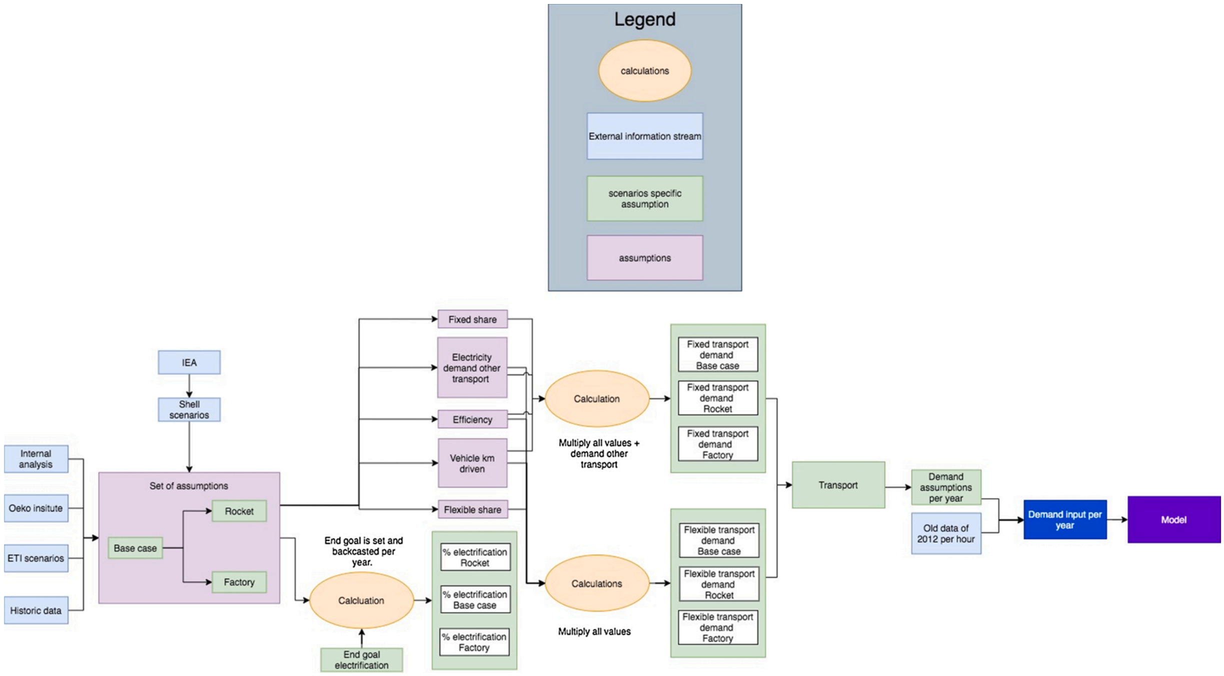
Additionally, further research needs to be carried out to validate the choice of the impact-uncertainty matrix. There are many other tools to classify changes, and the choice for this tool was the ability to link it to the different layers within the scenarios and the fact that this tool is well-known and simple to use. However, other tools might also be suitable for classifying changes and linking them to the different layers within the scenario.

The last recommendation refers to the development of a generic framework. A natural progression of this work is to apply the framework to scenarios discussing other industries. The test case was applied to the scenarios representing the electricity market. However, to confirm the generalization of the framework, it should be applied to other markets. Although the results may not be generically interpreted, an update was successfully executed using the framework. The results provide a starting point for other scenarios to be structurally updated.

**Declaration of Competing Interest**

The authors declare no conflict of interest.

**Appendix A**

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