Is Timber Coming Back to the Future of Construction?

Mass Timber Construction in the Dutch Biobased Circular Economy: A Backcasting Scenario Analysis

By Sam Dijsselbloem

March 22, 2022

MSc Forest and Nature Conservation Policy

Supervised by prof. dr. Bas Arts

Wageningen University & Research

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MSc Thesis Research at the Wageningen University & Research
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Abstract

As part of the strategy to become carbon neutral and in order to comply with the goals of the Paris Agreement, the Dutch government aims to establish a circular economy in 2050. Recent innovations in engineered biotic materials are being explored as renewable substitutes to primary fossil-based resources, which could play an important role in the establishment of the circular economy. This study presents a scenario analysis in which experts describe their desired future for mass timber construction as a substitute for conventional construction materials in 2030 and 2050 in the Netherlands. Through the methodological approach of combining existing explorative scenarios with backcasting exercises, experts identified obstacles and opportunities and formulated measures that, according to them, significantly contribute to the realisation of their desired future in 2030 and 2050. This desired future has been defined as: the substitution of as much abiotic construction materials with timber as possible within technological, sustainable and rational boundaries. Aiming for 20% timber in total material volume in 2030, and a minimum of 50% and up to 100% timber in 2050 in residential and non-residential buildings within the specified conditions. This desired future has been positioned as the point on the horizon in three explorative scenarios. These three scenarios are the Business-as-Usual scenario, the Warm scenario and the Paris scenario, which existed prior to the research and are based on the Deltascenarios by the Dutch Planbureau voor de Leefomgeving published in 2018. These explorative scenarios were utilized as contextual demarcations in the identification of obstacles, opportunities and measures. The first robust measure that significantly contributes to the accomplishment of the desired future has been identified as: the establishment of a honest, accurate and complete knowledgebase regarding construction materials and their carbon storing and emitting properties. Additionally, the establishment of a stable mass timber construction value chain with a continuous demand and sustainable supply of human and natural resources has also been identified as a robust measure that significantly contributes to the accomplishment of the desired future. The former of these two robust measures has been defined based on the most dominantly mentioned measures by the experts in three different scenarios, whereas the latter has been defined based on the most dominantly mentioned obstacles and opportunities by the experts. Together they form a bundle of measures and corresponding policy recommendations that are expected to significantly contribute to the accomplishment of a desired future in which timber comes back to the future of construction.

Keywords: *Circular Economy; Construction Sector; Biobased Materials; Mass Timber Construction; Scenario Analysis; Backcasting; Policy Measures & Recommendations*

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Summary

Forest ecosystems are widely recognised for their large role in climate change mitigation. The carbon sequestering capacities of trees allow the storing of atmospheric carbon in wood-tissue. Through this process of photosynthesis trees directly contribute to the reduction of carbon dioxide particles in the air and global warming. Simultaneously, trees become standing storages of emitted carbons until they decompose back into available organic matter. Recent engineering innovations allow wood products to significantly extent their longevity and add to a wide range of different possible product applications. These innovations are being emphasised in climate change mitigating strategies such as the EU Sustainable Bioeconomy Strategy as well as the European Green Deal. These strategies explore the possibilities of substituting abiotic and fossil-based materials with more sustainable biotic materials, resulting from biobased industries such as forestry and agriculture.

The innovations in engineered wood products, also known as mass timber, are becoming increasingly popular as a sustainable substitute for abiotic materials in the construction sector. The construction industry is among those with the largest resource demands globally and it consumes extensive amounts of energy in the processing and production of construction materials. The construction sector is therefore identified as one of the areas of urgent action underlined by the Intergovernmental Panel on Climate Change. Substituting conventional construction materials with biotic alternatives could have a significant impact on the use of primary and limited resources as well as energy consumption and the associated greenhouse gas emissions in the construction sector.

In this research an exploration of the development of mass timber construction in the Netherlands has been done based on a combined scenario analysis approach looking forward to 2030 and 2050. 15 experts present their desired future and give their own perspectives on the development of mass timber construction towards 2030 and 2050. Making use of a combined methodological approach of existing explorative scenarios and backcasting exercises, experts were allowed to describe this desired future and position this as their point on the horizon. The explorative scenarios provided a contextual demarcation within which obstacles and opportunities could be identified in association to their point on the horizon. Based on the identification of the most dominant measures, obstacles and opportunities, different robust measures could be formulated that are expected to significantly contribute to the accomplishment of the experts desired future for 2030 and 2050.

The 15 experts described a variety of desired futures for the development of mass timber construction towards 2030 and 2050. Notwithstanding this variation, they all agreed on the fact that mass timber construction is a means towards a larger goal, being the sustainable development of the construction sector and contributing to a better environment for the future. In combination with their expectations for mass timber construction this has been encapsulated in the following formulation of the desired future: Substituting as much abiotic construction materials with timber as possible within technological, sustainable and rational boundaries. This underlines the need to substitute conventional materials with timber, but also stresses that it must be done in an appropriate manner. This relates to the safety and durability of construction, use of sustainably produced materials and refraining from the use of excessive amounts of materials. Additionally, the experts on average aim for: 20% timber in total material volume in 2030, and a minimum of 50% and up to 100% timber in 2050 in residential and non-residential buildings within the specified conditions. These two specified goals for 2030 and 2050 define the experts desired future and has been positioned on the horizon of the following three scenarios.

The first scenario is the Business-as-Usual scenario. This self-explanatory scenario presents a future where nothing drastically changes compared to current situations. Contemporary trends and

developments continue in the same pace and no fundamental decisions are made. Within this scenario's contextual demarcations and with the desired future position on the horizon the experts identified obstacles, opportunities and associated measures. One of the most dominant obstacles being: the undeveloped value and processing chain of mass timber construction products in relation to the potential of a steep increase in demand. One of the more dominantly mentioned opportunities in this scenario is: the integration of carbon storing properties of materials and carbon pricing mechanisms in regulations. The experts identified the measure: the establishment of functional and honest carbon regulations and carbon pricing for construction materials, as one of the most important ones in the Business-as-Usual scenario.

The second scenario is the Warm scenario, based on the earlier publication of the Deltascenarios in 2018 by the Dutch Planbureau voor de Leefomgeving (PBL). In this scenario climate change progresses rapidly and socioeconomic development stagnates. These developments are driven by the unwillingness of governments to comply with climate agreements made during numerous conferences of the parties, resulting in a sense of distrust overshadowing international cooperation. Fossil-based resources remain dominant for a long time until its scarcity starts to increase costs. In this scenario one of the more dominantly mentioned obstacles is: the unavailability of timber resources and mass timber building elements as a result of climate change environmental impacts. One of the opportunities that is often mentioned in this scenario is: the growing societal awareness of climate change and its impacts and a demand for change. Providing complete and accurate information to decision-makers taking part in the material transition, is mentioned as one of the most important measures in this scenario.

The third and final scenario is the Paris scenario. This scenario is also part of the Deltascenarios and conforms to the goals agreed upon in the Paris agreement during the COP21 in 2015. In this scenario the progression of climate change slows down and becomes more temperate, socioeconomic development experiences a moderate growth. These developments are the results of fruitful cooperation between dedicated governments, globally addressing climate change and complying with the Paris Agreements to keep global warming under 1,5 degrees Celsius. In this scenario one of the more dominant obstacles has been described as: The unavailability of timber construction professionals in relation to a steep increase in demand. Among the dominant opportunities in this scenario is: the development and expansion of industrialised building innovations such as prefabricated modules. The experts explained that one of the more important measures in this scenario is: the improved availability of information in relation to carbon storing and emitting properties of construction materials to prevent false advertisement.

Two robust measures could be identified based on all the dominantly identified obstacles, opportunities and measures, a selection of which has been described above. The first robust measure includes four dominantly mentioned measures from all three scenarios and is formulated as: the establishment of a honest, accurate and complete knowledgebase regarding construction materials and their carbon storing and emitting properties. A second robust measure, based on dominantly identified obstacles and opportunities, has been formulated as: The establishment of a stable mass timber construction value chain with a continuous demand and sustainable supply of human and natural resources. These measures together form a bundle of policy recommendation that are expected to significantly contribute to the establishment of a desired future for mass timber construction in 2030 and 2050.

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1.1 A Biobased Circular Economy

Human induced climate change is driving global environments towards an ecological tipping point (Allen et al., 2018). This could have potentially devastating outcomes for natural and social systems around the world (Allen et al., 2018). A growing global awareness of climate change demands world leading organisations, politicians, scientists and societies to come up with sustainable solutions to accomplish a steep reduction in the use of fossil-based resources. To achieve this sustainable transition there is an urgent need for the transformation of current social systems and their relation to nature and the environment. Innovations in biological resources are increasingly being emphasised for their potential as a renewable substitute for fossil-based primary resources. Substituting these abiotic materials with biotic materials could result in a significant reduction in greenhouse gas emissions (Leskinen et al., 2018). This is being underlined as an important environmental policy strategy for the mitigation of climate change and has been translated into the biobased circular economy (European Commission, 2019).

In 2019 the European Commission (EC) presented *The European Green Deal* (EGD), aiming for a carbon neutral European Union in 2050 (European Commission, 2019). Central to this envisioned transition is the establishment of a biobased circular economy. This strategy encompasses the development of biologically renewable resources, increasing renewables in the energy sector, increasing energy efficiency in buildings and substituting carbon intensive abiotic products for sustainable biotic alternatives (European Commission, 2019).

The European Commission's Green Deal builds on their earlier *Bioeconomy Strategy* (2012) and its updated versions (2018) (European Commission, 2012, 2018b, 2020b). In 2012 the European Commission adopted this strategy to combat issues concerning climate change, natural resource depletion, greenhouse gas emissions and growing populations (European Commission, 2012). This strategy was founded on the concept of *The Bioeconomy*, a sustainable and innovative economic model that completely runs on biologically renewable products and allows the sustainable social and economic development of the European Union (European Commission, 2012). In 2018 the Bioeconomy Strategy was updated in the following publication: *A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment (European Commission, 2018b).* In this updated version 14 central actions are introduced, addressing major future challenges through the use and expansion of the bioeconomy's properties and innovations (European Commission, 2018b).

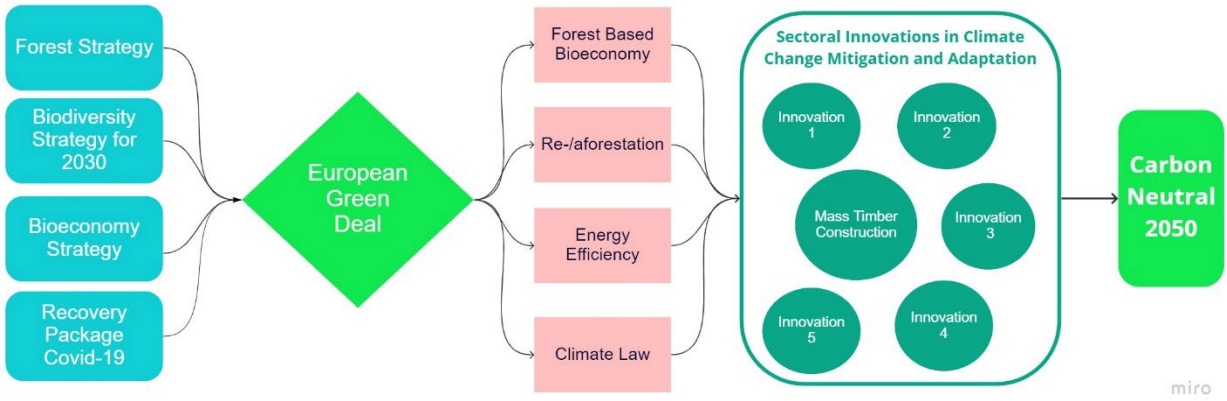

Figure 2: The European Commissions Strategies Towards a Carbon Neutral 2050 (By Author, 2022).

In the EGD special reservations have been made for the Forest sector, which has been given a large role in climate change adaptation and mitigation strategies. This is described in the new *EU Forest Strategy for 2030* that is delivered alongside the EGD (European Commission, 2021b). This strategy emphasise the multifunctionality of forests and the wide range of forest ecosystem services which could contribute to the sustainable development of the European Union (European Commission, 2020a). Most importantly, forests are increasingly being recognized for their carbon sequestration and storing capacities, the providing of biologically renewable resources and its social services (European Commission, 2020a). For these reasons the European Commission reserves a great role for forest-ecosystems and stresses the need for protection, reforestation and afforestation (European Commission, 2020a). This is illustrated by their pledge to plant at least 3 billion trees before 2030 (European Commission, 2021a)

For the forest-based sector this means a strong incentive for the use and innovation of forest-based products. This is recognised in the Forest Strategy *Roadmap 2020*: *"It*[1] *has to lay the foundations for innovation and promotion of new products that replace the intensive fossil-based materials and effectively contribute to a new climate neutral society"* (European Commission, 2020a, p. 2). The aims of the Bioeconomy strategy also align with the United Nation's SDGs. Among these, especially Goal 12: "*The adoption of sustainable consumption and production"*, and Goal 15: "*The protection, recovery and promotion of sustainable use of ecological land systems, sustainable forest management, prevention of desertification, and halting land degradation and biodiversity loss*" (United Nations, 2015). This clearly indicates the determination with which policymakers are searching for opportunities to transform contemporary societies away from carbon-based and towards biologically renewable products and resources.

The plans set out by the European Commission are vital for the future development of the European Union. The Commission's ambitions define the directions for EU member states to follow in their national policy. On the exception of European Laws used to set sustainable standards, it is mostly up to individual member states to implement climate policy and adhere to the European Commission's desires. Evidently, the individual EU member states respond differently on these targets and some governments are more determined than others. This makes it especially interesting to focus on the way specific member states respond to and implement the Commission's targets and envisioned directions.

In the Netherlands the government is aiming to achieve the goals of the Paris agreement and follow the targets set in the European Union. The Dutch government's ambition is to achieve a reduction of 55% in greenhouse gas emissions compared to 1990 in 2030 and become climate neutral in 2050 (Rijksoverheid Nederland, 2019). These targets demand that significant changes are made in all sectors of the Dutch economy before 2030 and 2050 respectively. To achieve these targets the Netherlands are particularly looking at the possibilities of the Circular Economy, aiming to accomplish complete circularity in 2050, as a central aspect in their sustainable transition (Ministerie IenM & Ministerie EZ, 2016).

To show their determination after the Paris Agreement of 2015, the Dutch Government adopted a National Climate Agreement in 2019. In this they describe their ambitions and depict five specific sectors of attention (Rijksoverheid Nederland, 2019). Earlier (inter)sectoral agreements have been made to set the agenda for climate policies, of which the adoption of a circular economy and the increased use of renewable resources has been an important aspect. The most important are the *Energieakkoord (2012);* which addresses the need to increase the share of renewable energy in the

[1] *New EU Forest Strategy for 2030*. European Commission (2020).

Netherlands, *Nederland circulair in 2050 (2016);* setting the agenda towards a circular economy in the Netherlands, and *Grondstoffenakkoord (2017);* with a specific focus on the production and consumption of natural resources and the enhancement of circular and renewable resource use (Ministerie IenM & Ministerie EZ, 2016, 2017; Sociaal Economische Raad, 2013).

The Build Environment is one of five focus points in the Dutch Climate Agreement, emphasising especially the adaptation and renovation of existing buildings to improve their thermal and, effectively but not exclusively, energy efficiency (Rijksoverheid Nederland, 2019). Yet, construction of the build environment is not overlooked, specific attention is granted in the agenda towards the circular economy strategy, especially in the *Transitie Agenda: Circulaire Bouweconomie* published in 2018 (Nelissen et al., 2018). In this report an action group consisting of diverse stakeholders, scientists and government officials design a concrete strategy to make construction in the Netherlands completely circular in 2050 (Nelissen et al., 2018). One of the important solutions brought forward that increases sustainability and circularity in construction is the use of biobased materials like timber (Nelissen et al., 2018). In the Netherlands multiple mass timber projects have been finished and others are under construction, for example HAUT, Patch22 & the Jakarta Hotel in Amsterdam.

Figure 3: The Dutch Strategies to become Carbon Neutral (By Author, 2022).

Exploring the role of the forest sector in the provisioning of biobased products in a circular bioeconomy is highly relevant for contemporary policy makers, forest sector stakeholders and societies as a whole. A central position for forest-based products could potentially contribute to climate change mitigation, through the substitution of fossil-based products as well as enhanced carbon sequestration in forest ecosystems, and allows sustainable development and economic growth (Leskinen et al., 2018).

Exploring the potential of mass timber construction as part of a biobased circular economy in the Netherlands gives valuable insights for policy makers and stakeholders, providing them with policy recommendations that could attain desirable sustainable outcomes based on future scenarios. Backcasting allows the design of these different policy options towards a predefined target central to the completely circular construction sector aimed for in 2050. Designing comparative options towards these targets does not predict the future nor future outcomes, rather it serves as a tool to strategically address complex future situations and problems (Hagemann, Gawel, Purkus, Pannicke, & Hauck, 2016).

1.2 The role of the Forests-based Sector

Planetary boundaries and its limited natural resources demand a radical restructuring of global production and consumption to allow long term development and economic growth without compromising natural systems (European Commission, 2012, 2018b). Natural limits to growth are being considered more seriously with climate change impacts around the world becoming increasingly severe and the indications of future scenarios with disruptive outcomes (Allen et al., 2018). This is especially being stressed in the light of growing global populations, expected to reach 9,77 billion in 2050 (United Nations, 2019). Recognizing that fossil-based resources are environmentally disruptive and becoming increasingly scarce results in the innovation and development of circularity and the use of renewable resources for products and energy. These innovations aim for sustainable economic

growth and development without depleting limited natural resources and have become a priority on the political agenda of governmental organisations (European Commission, 2018a).

As has been emphasised, forests are recognised as vital aspects of sustainable development and climate change adaptation and mitigation. Also, the provisioning of increased biodiversity and preservation along with social values of existence and recreation are underlined (European Commission, 2021b). Another major service that forests provide is the production of wood as a renewable resource with many possible applications that could play a major role in the establishment of biobased circular economies (Leskinen et al., 2018).

A wide range of wood-based products can be used to substitute conventional fossil-based production materials and reduce their carbon footprint (Leskinen et al., 2018). Biofuels, for example, are being developed to substitute oil and coal, paper and cardboard could have a role in substituting plastics, and wood-based fibres are increasingly being used for clothing (Leskinen et al., 2018). Other highly promising developments in wood-based products can be seen in the construction sector (Leskinen et al., 2018). Engineered wood products such as Cross Laminated Timber (CLT) allow for many new and sustainable developments in a sector that is traditionally conservative (Riala & Ilola, 2014). This also explains why there has been relatively little sustainable development in the construction sector, which still largely relies on fossil intensive building material like steel, cement and concrete (Himes & Busby, 2020).

1.3 Innovations in Construction

The construction sector is expected to play an important role in the development of a more sustainable future (Allen et al., 2018). Global trends show that cities around the world have been growing for decades and are expected to keep doing so (United Nations, 2019). Predictions from the United Nations show a global urban populations growth from 55% in 2018 to 68% in 2050, translating into an increase of 2.5 billion urban inhabitants (United Nations, 2019). These estimates highlight the central position cities will play in the future and emphasise the importance in creating a sustainable and healthy living environment for future generations. As cities will have to provide housing for over half of the global population the construction sector faces a major challenge. Increasing sustainability and efficiency in this sector is vital for the future and should aim for the best possible way *"to meet the needs of the present without compromising the ability of future generations to meet their own needs"* (Brundtland, 1987).

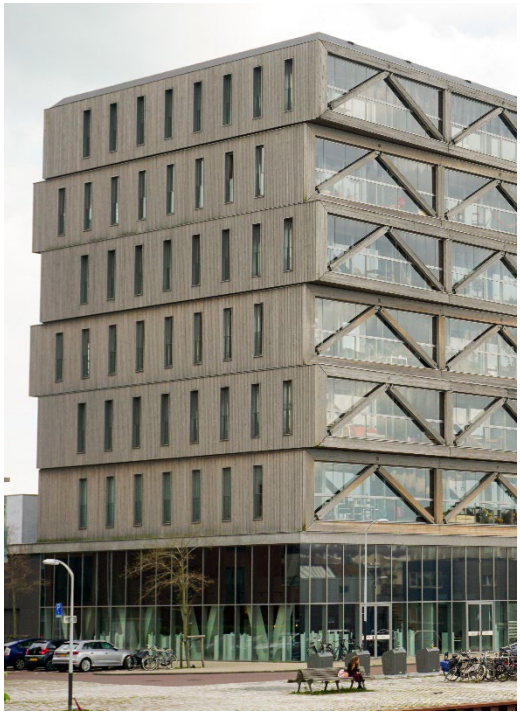

Figure 4: Patch 22, Amsterdam (By Author 2021).

Currently the construction sector is one of the most polluting industries globally. The United Nations Environmental Programme found that: " *The buildings and construction sector accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide (CO2) emissions in 2018, 11% of which resulted from manufacturing building materials and products such as steel, cement and glass"* (UNEP & Environment Programme, 2019). In their *special report on the impacts of global warming*, the Intergovernmental Panel on Climate Change (IPCC) (2018) identified buildings and construction as a

key field of action for climate change mitigation (Allen et al., 2018). Because of their large carbon footprint the sector can still accomplish significant carbon reductions, especially with technological innovations in place, like biobased building materials and innovations in timber use (Himes & Busby, 2020).

Since the 1990s the use of wood in construction has been increasing again (Mahapatra & Gustavsson, 2009). In the past centuries regulations for wood constructions in urban areas have been strict because of the occurrence of multiple large city fires in Western-Europe (Mahapatra & Gustavsson, 2009). However, due to innovations in mass timber products, regulations have been largely changed and allow the application of wood in multistorey buildings again (Harte, 2017; Mahapatra & Gustavsson, 2009; Riala & Ilola, 2014). The umbrella term *mass timber* includes multiple innovative application of engineered high-performance wood products that gives it the necessary characteristics to substitute steel and concrete building materials (Churkina et al., 2020; Ramage et al., 2017). These engineered products include Cross-Laminated Timber (CLT), Glue-Laminated Timber, parallel-strand lumber (PSL), laminated-strand lumber (LSL), laminated-veneer lumber (LVL) and wood I-joists among others (Ramage et al., 2017; Steel, Officer, & Ashley, 2021). Cross-Laminated Timber is one of the applications that has recently gained a lot of interest. This mass timber product consists of laminated sawn-timber that is bound in horizontal and vertical layers to create the necessary characteristics for construction purposes, other engineered products use slightly different methods depending on the purpose of the product (Kremer & Symmons, 2015). These mass timber products are being considered as the more circular, sustainable, economical, safe and thermal efficient substitutes of the currently dominating mineral-based building materials in the construction sector (Harte, 2017; Leskinen et al., 2018; Riala & Ilola, 2014).

In their life-cycle analysis Himes & Busby (2020) found that substituting conventional building materials with timber-based materials in multistorey buildings could reduce carbon emissions with 216 kg CO2e/m2 which is a reduction of 69% in construction phase emissions. Adopting this into urban planned construction could account for 9% annually reduced carbon emissions needed for the 2030 target to remain under 1,5 degrees Celsius temperature increase (Allen et al., 2018; Himes & Busby, 2020). This is in line with estimates made by the European Forest Institute (EFI) who calculate a “potential substituting benefit” of 89 million tons of CO2 globally in 2030 (Leskinen et al., 2018).

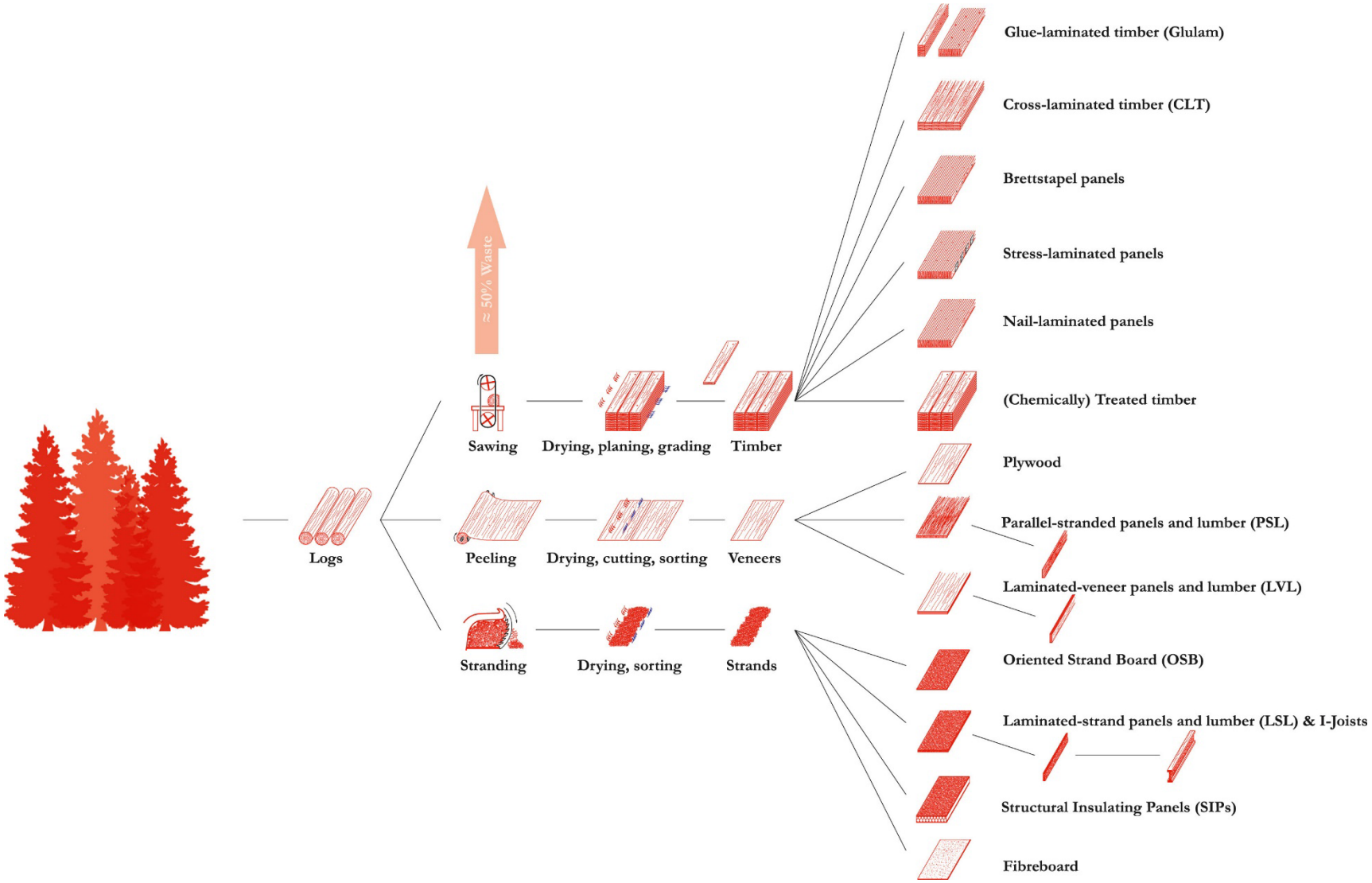

Figure 5: The Processing chain of engineered wood products (by Ramage et al., 2017).

1.4 Research Objective

The Netherlands is aiming to become carbon neutral in 2050 through the adoption of a circular economy. This demands the structural transformation of contemporary systems into more sustainable alternatives. Biobased resources are expected to play a major part in the circular economy and could potentially replace conventional systems running on abiotic and fossil-based resources. Forests and forest-based products are recognized as fundamental in this material transition and the establishment of biobased circular economies.

In this study a methodology of combined scenario approaches invites experts to present their personal perspectives for the development of mass timber construction in 2030 and 2050. The aim of this study is to develop a bundle of robust policy measures that are expected to significantly contribute to the desired future of mass timber construction, defined by a selection of diverse experts. This can be recognized as a central aspect in the sustainable transition of the construction sector in the Netherlands and is deemed key for construction to become completely circular in 2050.

The construction sector is highlighted because of the carbon intensive character of this sector (United Nations Environment Programme, 2021), the acknowledged room for improvement (Allen et al., 2018; Leskinen et al., 2018), the rapidly developing innovations and the expected growing demand for housing (United Nations, 2019). Residential and non-residential buildings are specified because they are identified as high substitution impact buildings and consequently recognized for their potential in emitted carbon reductions (Leskinen et al., 2018).

This research will be executed in the Netherland where academic research has hardly addressed the topic so far. The Dutch government has committed itself to the European Commission's ambitions and has expressed its aim to establish complete circularity in the construction sector by 2050 (Nelissen et al., 2018). This research will add to the existing literature covering similar studies in other EU member states and outside the EU borders. Additionally, this could contribute to a more extensive international study, bringing insights from multiple EU member states aiming for a similar future for construction together.

1.5 Research Questions

Central to this research are the following research question:

How do experts define the desired future for Mass Timber Construction in 2030 and 2050?

What obstacles and opportunities are expected to be encountered in the accomplishment of the desired future in 2050 based on three different socioeconomic and climatic scenarios?

What actions and measures substantiate a bundle of robust policy recommendations that are expected to significantly contribute to the accomplishment of the desired future in 2030 and 2050?

To answer these research questions a backcasting scenario approach will be utilized. This approach allows the respondents to explain their specific future expectations in relation to their personal desired future for 2050. This results in a specified set of robust measures which are expected to significantly contribute to the establishment of their desired future.

Chapter 2 - Theoretical Methodological Background

2.1 Strategic Foresight

The urgent need to transform modern-day systems of production and consumption into more sustainable alternatives demands decision-makers to think about the future. However, climate change effects remain highly uncertain and the fast pace of succeeding technological innovations and sustainable initiatives make it especially difficult to act in the interest of possible futures (Hagemann et al., 2016). This uncertainty simultaneously encourages the human desire and capability to look at the future and try to act accordingly.

Foresight approaches have been developed to provide decision-makers with practices to act upon possible or desired futures. The most dominant ones can be subdivided in two lines of thought; *la prospective* and *Strategic Foresights*. The French and American traditions, respectively, originated from somewhat different ontological assumptions. La prospective, established by Michel Godet and others, follows the belief that there can be many different futures at any given moment in time, and that the future as such is an active entity based on the choices and actions made at any given time (Coates, Durance, & Godet, 2010; Martin, 2010). La prospective therefor is inherently connected with decision-making as the main focus in the design of actions (Coates et al., 2010; Martin, 2010; Rohrbeck & Schwarz, 2013). This differs from the strategic foresight approach, originating from the American Military by Herman Khan, which follows the idea that the future is rather passive (Coates et al., 2010; Martin, 2010; Rounsevell & Metzger, 2010). The latter approach, therefor, is mostly used to prepare people for possible outcomes and allow them a better understanding of the forces at work (Coates et al., 2010). Notwithstanding their ontological differences, the two approaches apply similar methodologies. Both use the identification of system processes, the driving forces, key actors and desired outcomes as central elements in their foresight development (Coates et al., 2010). Also, it is a misconception that only one approach can or should be used, instead the two are deemed especially valuable as complementary approaches (De Bruin, Kok, & Hoogstra-Klein, 2017; Kok, van Vliet, Bärlund, Dubel, & Sendzimir, 2011).

In the academic literature these two approaches are also often referred to as normative (la prospective) and explorative (strategic foresight) typologies, for example, in scenario analysis. Additionally, a third typology can be distinguished, termed as the predictive (Karl Henrik Dreborg, 2004). This approach originates from the long history of thinking in predictions, dating back to periods prior to scientific based methods. Examples are, the predictions based on astrology, the divine or oracles (Karl Henrik Dreborg, 2004). The predictive aims to prepare for something or gain a realisation of what will happen. The more recent predictive modelling, for instance, can be applied for traffic forecasting among many other things (Karl Henrik Dreborg, 2004).

2.2 Scenario Analysis

Scenario analysis is one of the more commonly used foresight instruments and is increasingly being used (Hagemann et al., 2016). This can be seen especially with the growing number of environmental studies that are characterised with high uncertainty and complexity (Rounsevell & Metzger, 2010). Scientists design various scenarios to inform decision-makers by laying out the complex relationships between social and natural systems and its future impact (Allen et al., 2018). The Intergovernmental Panel on Climate Change has been a major leader in the application of scenario development, allowing insights in possible future outcomes of complex social-natural relations and their environmental implications (Allen et al., 2018; Rounsevell & Metzger, 2010). These scenarios facilitate decision-makers with directions and options, allowing them the possibility to make an informed decision against an uncertain background (Gausemeier, Fink, & Schlake, 1998).

Most scientific applications of scenario development are quantitative studies focussing on impact assessments through modelling (Hoogstra-Klein, Hengeveld, & de Jong, 2017), however, qualitative scenario development can be especially useful when analysing relations that are not easily quantifiable (Hagemann et al., 2016; Rounsevell & Metzger, 2010). The use of qualitative scenario approaches has grown largely since the 1970s with the analysis of human induced environmental change (Rounsevell & Metzger, 2010). Major scientific efforts have been made to allow a better understanding of climate change outcomes making use of mixed method research approaches such as combining quantitative modelling and qualitative scenarios. The most well-known examples are, the Global Environmental Outlook, Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change.(Rounsevell & Metzger, 2010).

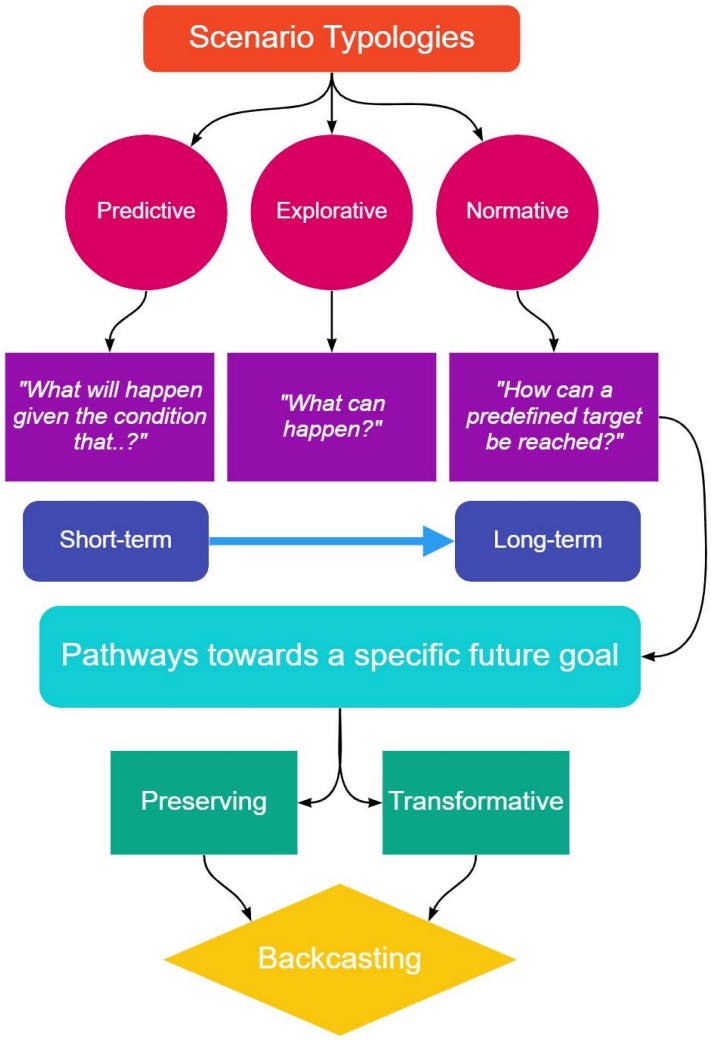

Figure 6: Scenario Typologies, based on Börjeson et al. (2006), (By Author, 2022)

As mentioned above, different typologies can be distinguished within scenario development, as has been done by Börjeson, Höjer, Dreborg, Ekvall, and Finnveden (2006). They broadly define three different types of scenarios: *Predictive*, *Explorative* and *Normative*, each providing the answer to a different question (Börjeson et al., 2006). The first scenario typology answers "*What will happen given the condition that…?"* and aims to predict the most likely development given a specific development on a relatively short term (Börjeson et al., 2006). The second scenario typology answers "*What can happen?",* focussing more broadly on different perspectives and developments with a longer time-horizon (Börjeson et al., 2006). The third scenario typology answers *"How can a predefined target be reached?"* and thus explicitly focusses on a specific future goal and what it takes to attain this (Börjeson et al., 2006). The latter scenario typology is deemed especially useful in situations where a rigorous transformation is aimed for spanning a large timescale and is put forward with the urgency needed to accomplish this goal (Börjeson et al., 2006). `

Within the normative scenario approach a differentiation is made between *preserving* scenarios and *transformative* scenarios. The major difference here is that preserving scenarios aim to solve the issue at hand within the existing system and the transformative scenario aims at structurally changing the system to solve the problem (Börjeson et al., 2006). A scenario method that is considered to be very useful, especially for the development of normative scenarios, is *backcasting (Karl H Dreborg, 1996; Höjer & Mattsson, 2000; Robinson, Burch, Talwar, O'Shea, & Walsh, 2011; Zimmermann, Darkow, & Heiko, 2012).* This method allows the researcher to work back from a set target and explore the different pathways that attain this specific target (Karl H Dreborg, 1996). This approach is an alternative to the more commonly used forecasting scenario which explores possible futures given a certain

development or condition (Börjeson et al., 2006). Backcasting is deemed especially desirable to approach complex and system wide problems with high levels of urgency. Environmental issues and sustainable transformations make very applicable studies for this approach because of their holistic characteristics, long time-horizon and complexity (Karl H Dreborg, 1996).

More recently, researchers have identified that the combined use of different scenario approaches can also be a feasible and valuable research method (De Bruin et al., 2017; Kok et al., 2011). This is especially true for situations where the researcher is dealing with long time-horizons and highly complex systems, both adding to the encountered level of uncertainty (De Bruin et al., 2017; Kok et al., 2011). Additionally, uncertainty in the methodological approach of backcasting and explorative scenarios is recognized as inherent and unavoidable and treated as such (De Bruin et al., 2017).

One of the strengths that is underlined in this combined approach is the use of explorative scenarios, integrating external trends and developments into possible future outcomes as a contextual demarcation, within which respondents are enabled to develop a normative scenario through backcasting (De Bruin et al., 2017). This provides the respondents with vantage points assisting their normative pathways. Also, this allows the researcher to expose the respondents to different possible explorative futures and hence test their normative scenarios against these backgrounds (De Bruin et al., 2017). Through the use and comparison of these different explorative scenarios and the corresponding backcasts robust findings can be identified, defined by their occurrence in all or multiple of the different explorative scenarios (De Bruin et al., 2017; Kok et al., 2011).

The academic literature includes different scenario analysis studies that cover one or more aspects of the bioeconomy and the corresponding consumption and production transition towards biobased products (Eriksson et al., 2012; Hagemann et al., 2016; Kremer & Symmons, 2015; Lundholm, Black, Corrigan, & Nieuwenhuis, 2020; Peñaloza, Erlandsson, Berlin, Wålinder, & Falk, 2018), yet seemingly lacks a scenarios analysis for mass timber construction adoption in the Netherlands. Therefore, this study will be a valuable addition to comparable scenarios developed in Sweden (Peñaloza et al., 2018), Germany (Hagemann et al., 2016) and Australia (Kremer & Symmons, 2015). This is especially true because of the combined approach of complementary use of explorative and normative scenarios.

The Dutch government aims to achieve a completely circular economy in 2050 and 50% circularity in 2030. For these ambitions to become reality some sectors needs to substantially reduce their primary resource use. The construction sector, being one of the most resource intensive industries, is one of those sectors that has to drastically change their conventional methods to reach this goal. One of the innovations that is currently emphasised is the use of timber as a biotic renewable resource that could substituted conventional materials. The application of timber and engineered wood products could therefore play a central role in the construction sector's transition towards circularity in the Netherlands in 2050. This research aims to identify and develop a bundle of robust policy measures that are expected to significantly contribute to the establishment of a desired future for mass timber construction in residential and non-residential buildings as has been expressed by experts.

To be able to formulate a package of robust measures, the future obstacles and possibilities, expected to be encountered in the establishment of the desired future, have to be identified first. This confronts the inherent issue of future uncertainty which makes it very difficult to express what obstacles and opportunities could be encountered. To solve this issue of uncertainty this study applies a scenario approach, allowing respondents to position themselves within a predefined possible future outcome.

2.3 Deltascenarios

These possible future outcomes are presented in different scenarios that have been formulated in the Deltascenarios by the Dutch PBL (*Planbureau voor de Leefomgeving)*. Respondents are asked to describe their expected obstacles and opportunities in relation to the identified desired future positioned in the specific scenarios. This also allows the identification of measures that are expected to significantly contribute to overcoming and utilising those obstacles and opportunities, and accomplish the desired future. Subsequently, these measures are tested for their robustness based on their importance and presence in all three the different scenarios. When a specific measure is considered to make a significant contribution in all the different scenarios it is deemed robust.

As previously described, the decision has been made to apply a combined methodological approach of explorative scenarios and backcasting in this study. In the following section the argumentation behind the use of the predefined explorative Deltascenarios and the specific external developments that characterise these scenarios will be discussed. Furthermore, the scenarios Warm and Paris will be described more extensively than the other Deltascenarios and the decision to utilize these specific scenarios will be elaborated on. Lastly, the practical application of the scenarios during the semi-structured expert interviews will be described and the decisions made in this regard will be explained.

The decision to use priorly existing explorative scenarios from the literature was predominantly based on the consideration of the scope of this research. Developing explorative scenarios can be considered as a study in itself and with an additional normative scenario study it would likely have exceeded the timeframe set out for this study. Another reasons to use predefined explorative scenarios is the ability to use predictions about broad and societal developments such as socio-economic development and climate change (Hoogstra-Klein et al., 2017). These and similar scenario approaches demand large amounts of data about trends and conditions on numerous variables to be able to model possible future outcomes, data that is also beyond the scope of this research. Therefore it is argued that in the interest of the quality and focus of this study the use of predefined explorative scenarios as a context for external developments in a possible future was the most sensible choice.

The Deltascenarios are exploratively developed scenarios periodically published and commissioned by Deltares, a Technological institute that is especially focussed on the river delta and catchments in the Netherlands. The scenarios exist of four possible future outcomes developed on two main axis which were developed by PBL (*Planbureau voor de Leefomgeving),* CPB (Centraal Planbureau), KNMI (Koninklijk Nederlandse Meteorologisch Instituut) and Wageningen University and Research. The vertical axis represents the *Welvaart en Leefomgeving*-Scenarios that have been developed by PBL and CPB, which include socio-economic trends and their possible future outcomes, whereas the horizontal axis represents the climate-scenarios of the KNMI presenting possible future outcomes in relation to climate change. Through these two axis, four different scenarios are developed in relation to socio-economic and climate change developments and their impacts on possible future outcomes for 2050 and 2085 (Wolters, Van Den Born, Dammers, & Reinhard, 2018).

The Deltascenarios have been selected for this study because they present two highly relevant, yet integrated conditions for the design and analysis of normative scenarios. The conditions that are presented in these scenarios are well suited to represent an integrated look into possible future conditions. These possible future outcomes allow the respondents to think about an alternative reality to contemporary situations without losing credibility of such a future scenario. Simultaneously, the conditions presented in the scenarios align with the specific topic of interest, especially in terms of climate policies. This allowed the respondents to reflect on how the developments could potentially impact the topic. Because of the semi-structured expert interviewing approach a time limitation

existed in the amount of scenarios that could be employed. To restrain the interviews to a maximum of one hour approximately including the indication of the desired future and the business as usual scenario, only one out of two selected Deltascenarios could be included per interview.

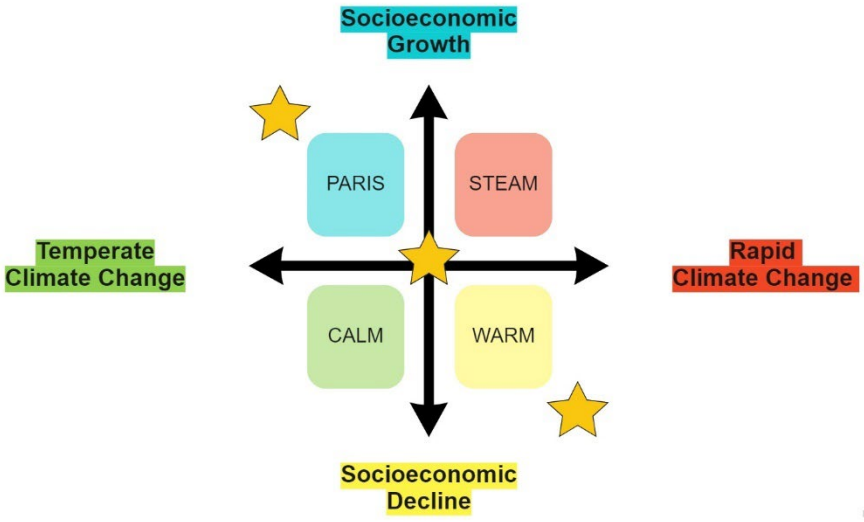

Figure 7: Overview of the Deltascenarios cross diagram Based on Wolters et al. (2018), Stars Indicate (left to right): the Paris Scenario, the Business-as-Usual Scenario & the Warm Scenario, (By Author, 2022)

The four Deltascenarios are the following:

- Paris: Socioeconomic growth and temperate climate change
- Steam: Socioeconomic growth and rapid climate change
- Rust: Socioeconomic decline and temperate climate change
- Warm: Socioeconomic decline and rapid climate change

In this study the decision has been made to use two out of four Deltascenarios and one additional Business-as-Usual scenario. The Paris and the Warm scenarios have been selected from the four total Deltascenarios. Primarily, the Paris scenario has been selected because this scenario is, unlike the others, subject to the influence of policies and agreements. The Paris scenario has been developed to comfort to the agreements made during COP21 in Paris in 2015. This presents an additional scenario attribute which is deemed as a valuable contribution to this study. Based on the selection of the Paris scenario it was deemed sensible to select its counterpoint. Warm being the direct opposite scenario has therefore been selected as the secondary scenario to be employed in this research. Notwithstanding, the Warm scenario also presents very interesting features in relation to rapid climate change and the socioeconomic developments, contributing another insightful and interesting possible future outcome. Figure 1 presents an overview of the four scenarios along the two axis, the stars indicate the selected scenarios, the middle star is placed to indicate the Business-as-Usual scenario.

The Paris scenario is slightly different than the other scenarios because it has been developed in consideration of the Paris Agreements of the COP 2015. In this scenario the necessary actions are made to stay underneath the global warming of 1.5 degrees Celsius, consequently aiming for a reduction of 80 – 90 percent in emitted greenhouse gasses (Wolters et al., 2018). In this scenario socioeconomic wealth is growing nationally and globally, states are devoted to the Paris Agreements and cooperate to accomplish these goals. This results in a widespread sense of international trust which also allows an increase in international trade. Because of the international devotion to the Paris Agreements the

pace of climate change progression is brought back and the impacts become more temperate. Technological development is also boosted because of this improved economic environment and the energy transition is made quickly (Wolters et al., 2018).

The Warm scenario does not include climate policies, or any other policies for that matter. In this scenario national and global socioeconomic wealth decreases, states do not conform to any international climate agreements and technological developments and innovations are very limited (Wolters et al., 2018). Because of this international trust becomes very deprived and this negatively impacts international trade. Simultaneously, the neglect of technological development and climate policy results in a very slow energy transition to renewable resources and fossil fuels remain dominant for a long time. Eventually fossil-based resources become increasingly scarce and therefore more expansive to extract which gives an impulse to renewable resources allowing the energy transition to take place (Wolters et al., 2018). However, because of the long lasting dominance of fossil-based resources, climate change has increased rapidly and the earth is warming.

Additionally the business as usual scenario has been described by its definition. The government does not make system wide and impactful decisions and continuous on the same foot as has been done in previous years. This can also be seen in the similar developments with regard to socioeconomic trends and the continued pace of progressing climate change. The international climate conferences remain on the agenda as has been yet remain without substantial interventions in society.

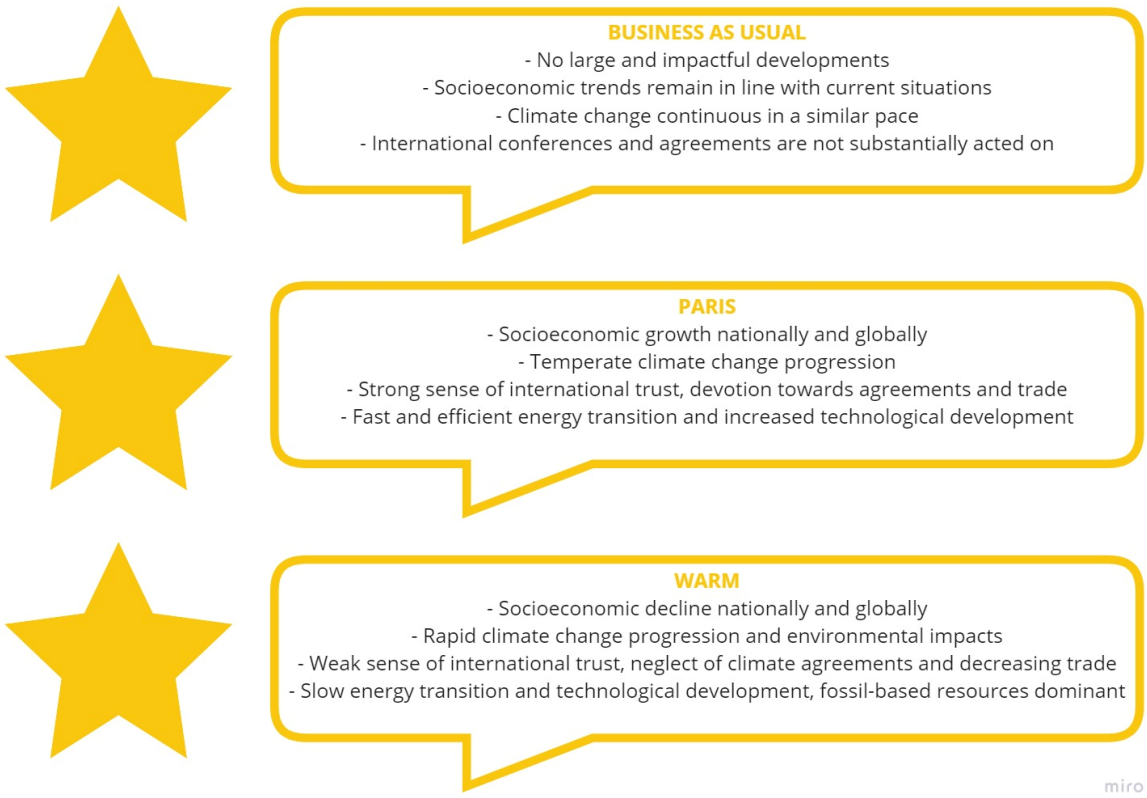

Figure 8: Overview of basic Deltascenario attributes (By Author, 2022)

The data collected in this research is of qualitative character. The personal perspective of experts is regarded essential and the way they describe or approach these scenarios, their desired future and

the associated obstacles and opportunities are vital insights for the answering of the research questions. For this purpose the focus has been on the collection of primary data from expert interviews. Additionally secondary data has been used mostly for the description of possible future outcomes in scenarios. Besides this, academic articles were utilized to establish the fundaments and the23nwilltion of the problem statement. Also, the researcher executed extensive readings of academic and grey literature to become acquainted with the contemporary trends and developments.

2.4 Data Collection Approach

The initial methodological design in this study included the use of a live backcasting workshop to be held on the Wageningen University and Research Campus. However, due to several difficulties concerning COVID-19, topic exhaustion and expert availability, this workshop had to be cancelled. Because of the limited time-frame for this research the decision was made to not reschedule the workshop as this would have delayed the process too much. The data collection method was redesigned into semi-structured expert interviews maintaining the previously designed explorative and backcasting combined scenario approach. Therefore the aim of these interviews was to integrate the same procedure as had been planned for the workshop including the presentation of the different explorative scenarios. The backcasting steps described in Kok et al. (2011) were used as a guidance for this procedure and were also incorporated in the semi-structured interview-guide as its mainline. The interviews were consequently structured by the following five steps respectively (based on the outlined steps by Kok et al. (2011)): (1) Respondents establish the end-point defined as desired future, (2) respondents indicate obstacles and opportunities necessary to realise the desired future, (3) respondents define the medium short term goals (2030) (4) respondents identify measures corresponding to obstacles, opportunities and key actors (5) robust measures are identified based on the most dominantly mentioned measures.

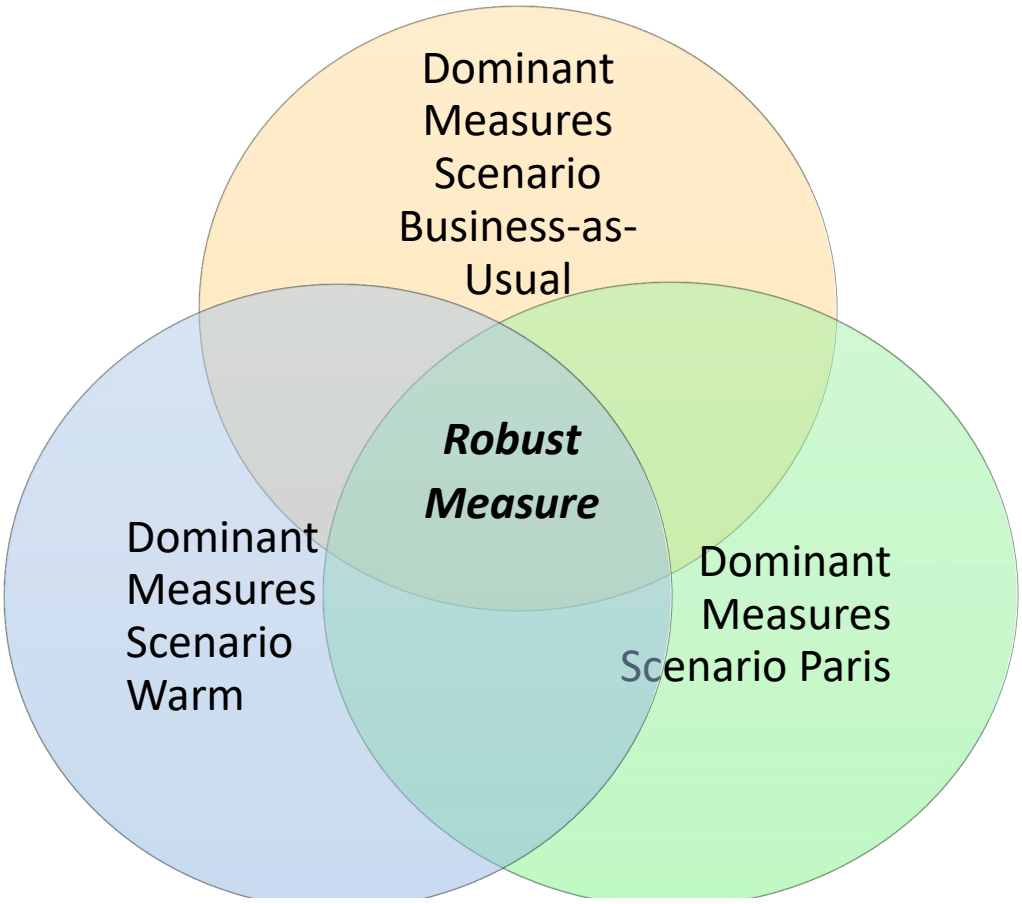

Figure 9: The Robust Measure is established based on the most dominantly mentioned measures in all three scenarios (By Author, 2022)

2.5 Data collection methods

2.5.1 Interviews

Alternatively to the more common use of workshops in this methodological approach (De Bruin et al., 2017; Kok et al., 2011), this research redesigned these steps into semi-structured expert interviews as a data collection method. This decision was not made completely voluntarily as described above, yet presented an interesting experimental opportunity for an alternative methodological approach. Corresponding to the five steps, the interview started with the identification of a desired future. This point could be established based on questions concerning the experts desires in an ideal situation, challenging them to be openminded about the possibilities and look beyond what they know. The desired future, after its establishment, maintained a central position in the continuation of the entire interview, and was also referred to as the point on the horizon.

Followed by this was the presentation of the first explorative scenario, the Business as Usual scenario. This is the only scenario that has been addressed in all the interviews. The Business as Usual scenario served a very important purpose as it allowed the experts to explain the obstacles and opportunities that they expected to encounter in the establishment of their desired future within a context that was relatively close to the contemporary reality. The business as usual scenario, being illustrated as a scenario where impactful decisions and developments fail to occur, therefore invited the experts to give their perspective inside a familiar context. As has been done similarly within all the other scenarios, the obstacles and opportunities were indicated and the appropriate measures identified as well as the associated key actors.

After the business as usual scenario the experts were presented with one of the two other explorative scenarios, the Warm scenario or the Paris scenario. These scenarios were described by their specific characteristics and possible future outcomes. The scenarios therefore presented the experts a different and less known context for the performance of the backcasting exercise. Most notably in these scenarios was the steep increase in the demand for a more imaginative approach to the indication of obstacles, opportunities and the best fitting measures. Experts were challenged to step outside of what they knew about contemporary context and had to position themselves and their desired future within a context of external developments that could potentially occur in the future. From this position they would engage in the backcasting exercise and apply their normative scenario.

In these three parts of the semi-structured expert interviews, the first 4 steps by Kok et al. (2011) have been included. The final step; identification of robust measures, could not be executed during the individual interviews because it necessitated the comparison of all results and the identification of corresponding findings among all three explorative scenarios. This final step is therefore integrated in the data analysis and will be described in more detail below.

2.5.2 Interview Table

A specially designed table was used to permit the researcher to make succinct notes during the interviews in an efficient and undisruptive manner. This table has been used during all the interviews and mostly focussed on the identification of the four key research concepts, the desired future (*Doelen)*, the obstacles (*Obstakels)*, the opportunities (*Kansen)* and the measures or actions (*Acties)*. The table included different sections for the business as usual, Warm and Paris scenarios and effectively served as an overview on which the researcher could fall back. This has been experienced as especially efficient when experts were experiencing difficulties with repositioning themselves in the different scenarios. It allowed the researcher to redirect questions based on a previously identified indicator and if or if not it would be different in the given scenario. The table also became a valuable

data source because it contained the main indicators resulting from the interviews. This will be extended on in more detail in the data analysis section.

	Desired	Expected	Minimal	
Future Goals				
	Obstacles	Measures	Opportunities	Measure
Business as Usual				
Warm				
Paris				

Figure 10: Table used for the collection of interview notes

2.6 Participant Selection

Because the methodological approach of the research demanded respondents to be able to reflect on different explorative scenarios and their desired future in relation to the research topic, the participants had to have a relatively clear understanding of the topic and the different spheres of influence. Therefore a level of expertise was desired from all the participants to be able to sufficiently participate in the research. In the identification of these participants, or rather experts, it became clear that this specific participant pool was fairly small. Something that could have been expected because mass timber construction was and still is a niche market. This small participant pool resulted in an advantage as well as a disadvantage. Because of the small scale of this new innovation it seemed like most of the experts knew each other and could often identify specific specialities within the timber construction expertise. This allowed the researcher to effectively make use of the snowball sampling methodology. Occasionally participants would forward interview requests towards other experts of which they expected to be willing to participate and contribute and often at the end of an interview names, initiatives and companies were referred to as potentially interesting. The snowball sampling method therefore allowed the researcher to effectively identify new and valuable experts with particular standpoints. After identification, however, it also became clear that in many occasions experts were very busy or had already been exhausted on the topic because of the rapidly increasing media attention. The latter became more of an issue when several large construction companies decided to invest in mass timber factories which spiked media interests even more.

Some additional sources for the identification of experts have also been utilised. Through the Wageningen University and Research network the researcher was invited to participate in two excursions concerning the development and application of Dutch timber production in construction.

This group included several housing corporations, an influential construction company and forest managers among others. Within this group the researcher was allowed to send interview request to the experts identified and acquainted with during the excursions. Another addition in the participant selection procedure was the participation in a multiday exhibition of new innovations in construction (Building Holland 2021), this included the participation in numerous presentations and workshops. A final addition to the participant selection was the participation in three live events in Amsterdam hosted by *Pakhuis de Zwijger*. In these sessions experts were invited to come and discuss three different topics within timber construction innovations, from these expert panels participant have been identified and invited to participate in the interview.

The combination of participant selection methods resulted in a total list of 15 participants. Each of these participants were included based on their specific knowledge field and expertise. Together the 15 experts encompassed a substantial part of the timber construction value chain, ranging from forest managers to construction workers. A list of the included experts can be found underneath this section also indicating their specific expertise. The inclusion of the expert names have been approved in all occasions. In addition, all citations have been subjected to a round of feedback before being approved by the individual experts, the approved citations were translated by the author.

Naam	*Profession*		*Scenario*
Eric de Munck	Centrum Hout	Manager	Business as Usual (BaU)
Henk Wanningen	Staatsbosbeheer	Sr. Business Developer	BaU & Paris
Imme Groet	C-creators / MRA-houtbouw	Project manager	BaU & Warm
Ingrid Hulshoff	Syntrus Achmea	Portfolio manager	BaU & Paris
Irma Thijssen	Netherlands Enterprise Agency (RVO)	Sr. Advisor Sustainable Construction	BaU & Paris
Jan Oldenburger	Probos	Director	BaU & Warm
Jan-Willem van der Groep	Gideon / Ministry of Agriculture Nature and Food Quality (Min. LNV)	Accelerator	BaU & Paris
Jetske Thielen	Lente Housing Corporations	Accelerator	BaU & Paris
Lidewij Lenders	Maatworks Architects	Co-founder	BaU & Warm
Maarten Willemen	Algemene Vereniging Inlands Hout (AVIH) / PEFC Netherlands	Director	BaU & Warm
Mark Beuving	Gideon / Residents Position / Marketing	Accelerator	BaU & Warm
Mark Kemna	FSC Netherlands / Lente Corporaties	Director	BaU & Paris
Michel Post	ORIO Architects / Vereniging Integrale Bio-Logische Architectuur (VIBA)	Owner / Chairman	BaU & Paris
Sandra Nap	Holland Houtland	Accelerator	BaU & Warm
Wim Sturris	De Groot Vroomshoop	Director	BaU & Warm

Figure 11: List of Participating Experts

2.7 Data Analysis

The collected data included 15 extensive expert interviews with an average duration of approximately one hour. All interviews have been transcribed in detail by the researcher and occasionally in assistance of online transcription software called *Trint*. For the utilization of this software the audio fragments needed to be of very high quality to produce a reasonable transcript. In all the instances that Trint has been used the researcher verified the produced transcripts by another extensive walkthrough. For the instances where the audio fragments were not of the best quality the transcription software would be of no practical use and the researcher transcribed the interviews by hand. However extensive and time consuming this process was, it did produce the best and most complete transcripts. When all interviews were transcribed they were merged into one combination document counting 176 pages of transcript that was used for the data analysis.

Additionally to the interview transcripts, the collected data also included the interview notes which were efficiently and succinctly collected in predefined tables. The tables, as has been discussed, included the main research concepts and consequently served a great purpose during the early data analysis phase. This will be specified more detailed in the following sections.

Because of the large body of textual data the qualitative analysing software ATLAS.ti 22 was used. This software has been especially developed for the dissecting of large bodies of text through the selection of quotations and its categorisation based on coding. Before the whole dataset was analysed a primary coding-scheme was developed (Appendix 1). The development of this initial coding-scheme consisted of two different approaches. First of all the coding was based on the research concepts which are the desired future, obstacles, opportunities and measures. These concepts were the basis to the more deductive approach of selective coding, which contributed a substantial part of the coding-scheme. Additionally, open coding has been used as an approach to be able to incorporate new information and insights gained during the interviews itself which were not directly connected to the research concepts.

The initial selective coding approach could be done quite efficient based on the tables including the interview notes. These tables already focussed on the research concepts and therefore the collection of all different tables could be used to make an initial coding-scheme with the analysis of these succinct findings. From these tables a primary list of categories and codes were derived and an initial division of the desired futures could be identified.

With this coding-scheme the researcher analysed the combined interview transcript document completely adding and changing codes during the process based on the open coding approach. After the whole document was coded the researcher returned to the coding-scheme to merge and adapt overlapping or irrelevant codes and outliers that did not contribute to the findings and allocate the remaining codes into corresponding categories (Appendix 1). This was followed by an additional walkthrough which allowed the researcher to re-assign or add quotations to the new coding-scheme where necessary. This analysis resulted in a total of 1127 quotations related to 207 different codes. In the appendix an overview of all applied codes Is included, giving a very detailed look in the most mentioned aspects associated to the research concepts.

The total amount of codes were categorised based on the most clearly identified trends and broadly defined sphere of influences mentioned by the experts. It can be noticed that the same categories have been indicated for the different research concepts, this is because the categories represent a broader aspects of the spheres of influence and therefore in numerous occasions involve opportunities as well as obstacles, and inevitably the associated measures. For a more detailed insight in the coding scheme and the distribution of the codes into categories see Appendix 1-5.

Chapter 3 - Results

3.1 The point on the Horizon

While conducting expert interviews an extensive amount of data has been gathered, providing detailed insights in expert perspectives and visions for different possible future outcomes and its impact on the development of mass timber construction. Central to the expert perspective is their future desire for the development of mass timber construction towards 2050. This point on the horizon has shown to be influenced by expert's expectations given at two points in time, 2030 and 2050.

The majority of the experts explained that they expect a significant increase in the volume of timber building materials in the forthcoming decade. Their expectations vary between the substitution of 10 to 50 percent of total building materials by mass timber for residential and non-residential construction projects before 2030.

> *In my personal perception of 2025 timber construction has gained a substantial position of more than 20%. This is particularly the case when you look at the definition that we maintain for timber construction, focusing especially on timber frame constructions, and within this definition I do hope to see at least 20% of construction to be executed in timber by 2025. However, it has to be done in a sustainable manner and especially the sustainable management and quality of the forests in Europe sometimes worries me. (Imme Groet, personal communication, November 23, 2021)*

Their desired future on average exceeds this margin and is referred to or can be explained as: *as much as possible within technological, sustainable, and rational boundaries*. This refers to respectively; technical engineering necessities considering safety and durability, the use and guaranteeing of sustainable practices in timber production, and making use of the available resources in a circular and responsible manner. When these conditions can be maintained and are not compromised in the development of mass timber construction, the experts desire a significant increase in the adoption of this building material.

> *Whatever happens in the next few years is less important to me, the most important thing is the long term vision. In ten year from now I believe that we should have made a sustainable turn and in thirty years from now the goal should be to build everything in timber where possible technically and resource efficiently. Especially when looking at residential and non-residential buildings. (Maarten Willemen, personal communication, December 2, 2021)*

Experts often explain that their ambitions for mass timber construction within these specific conditions is very large and when these conditions are ensured their future desire extents to the substitution of the maximum possible attainable amount of fossil-based materials with timber and biobased materials.

> *In my ideal future the amount of timber houses is maximized, yet remains within the conditions of sustainable practice. Particularly the sustainable use of resource which are necessary to guarantee its availability. (Jan Oldenburger, personal communication, November 16, 2021)*

The experts are significantly more ambitious indicating their desired future for 2050, however the majority also stresses 2050 is beyond their scope and often add hesitation or conditions. These conditions are very much in line with the ones mentioned above and can therefore be summarised as: *within technological, sustainable and rational boundaries.* One of the more central ideas is that the use of timber should not go at the expanse of other important things such as construction safety and durability, but also the state and quality of forests globally.

> *There will always be a need to assess the optimal use of different materials and their application within buildings. However, looking at frame constructions specifically I believe that in 2050 most could be executed in timber. Yet, this still strongly depends on the quality and health of the European forests and their production in regard to climate change impacts. (Eric de Munck, personal communication, November 9, 2021)*

Some experts explain that they expect timber construction to become mainstream in 2050 and that a complete regime shift would occur making traditional materials such as concrete and steel the exception rather than the rule.

> *I believe that timber construction in 2050 is maximized. I believe it could be between 90 and 100 percent where possible. This would become the new standard: timber where possible and concrete or steel where necessary. A lot of parties are already applying this standard in my understanding. (Mark Beuving, personal communication, November 17, 2021)*

Also, the time frame towards 2050 seems to result in substantially less quantitatively specified answers for their desired future compared to 2030. Seemingly the shorter timeframe towards 2030 allows respondents to quantify their desired future based on what they know and what they tend to expect. Approaching 2050 however seems to demand more of an creative exploration of the desired future resulting in a more diverse and qualitative perspective.

> *Timber construction is a means to achieve sustainable and healthy buildings compared to conventional construction, however, timber construction should not be the end goal. Perhaps the important questions are more fundamental, such as "do we have to build more?". Natural systems are always balanced and I hope that future societies will pursue this ideal. Instead of unlimited growth aim for a fundamentally balanced and circular system. (Lidewij Lenders, personal communication, January 13, 2022)*

Most noticeably in the expert's perspectives on their desired future for timber construction is the notion that timber construction is not a goal but a means towards a more sustainable and balanced future. Consistent within their broad and diverse future perspectives is therefore the strong believe that timber could benefit the construction sector and considerably reduce its carbon footprint. This greater goal is also clearly represented in the desired future's conditions for 2030 and 2050 that have been quoted above, emphasising the sensible, sustainable and responsible use of resources as the fundamental principle.

> *I would say: in 2030 50 precent less CO2 intensive materials and this reduction will be completely covered with biobased alternatives, or materials that are released from demolition and disassembly. When you extrapolate this motion towards 2050 you can assume that all the buildings in 2050 will be largely biobased. (Jan Willem van de Groep, personal communication, November 18, 20210*

> *There are all kinds of different developments happening that need to be taken into account and this makes it rather difficult to predict the future, especially as far ahead as 2050. However, ideally I do believe that a substantial share of the construction materials used today could be substituted for timber-based materials and timber construction products. (Erik de Munck, personal communication, November 9, 2021)*

On average the experts expect the use of timber in residential and non-residential construction to reach 10 to 30% in volume of building materials in 2030 with some deviations going up to 50%. Their desired future for the use of timber in residential and non-residential construction for 2030 is 20% within technological, sustainable and rational boundaries.

The experts desired future for the use of timber in 2050 in residential and non-residential construction is to exceed the greater part of building materials in volume, ranging from 50 to 100% in volume of building materials that lay within technological, sustainable and rational boundaries.

Based on these results the point on the horizon has been defined as:

Substituting as much abiotic construction materials with timber as possible within technological, sustainable and rational boundaries. Aiming for 20% timber in total material volume in 2030, and a minimum of 50% and up to 100% timber in 2050 in residential and non-residential buildings within the specified conditions.

3.2 The Business-as-Usual Scenario

The first scenario that has been explored by all experts is the baseline scenario, *Business as Usual*. In this scenario the first and most noticeable result is the ability of experts to relatively easy identify possible obstacles, opportunities and measures. This could be explained by the fact that the business-as-usual scenario is by definition the closest scenario to the present-day reality and therefor experts could approach it from their immediate position and experiences. In the following the most significant obstacles, opportunities and measures from the business-as-usual scenario will be demonstrated by means of interview quotations.

3.2.1 Obstacles

Identified through the practice of detailed coding of interview transcripts, the most mentioned obstacle in the business-as-usual scenario is *the unavailability of timber resources as a building material.* This obstacle is shown to be strongly related to several obstacles associated with a quick and exponential growth in the demand of timber building materials. One of the most prominent of these are the risk of unsustainable forest management and exploitation of forest resources.

> *The sustainable principles are about the management of forests in such manner that future generations are capable of meeting their needs as well. When we become overenthusiastic we might start to approach this development linearly instead of circular again. Therefore the obstacle is that we could carry this ambition to far and forget to be circular and sustainable, resulting in excessive harvesting and unsustainable practices. This would be against the forests and future generations interest. Therefore the focus should be on harvesting resources from forests that are proven to be sustainably managed and thus forests that are certified by FSC or PEFC. (Henk Wanningen, personal communication, December 23, 2021)*

The primary practices of sustainable forest management are represented by forest management certificates. One of the more fundamental principles of these certifications is to keep the standing biomass in the forest, based on the number of trees and their diameters, stable and therefor guarantee the future existence of the forest. Some experts, however, fear that with increasing demands for timber the focus on certified forest products could be neglected and consequently the sustainable management of forests.

> *I notice that timber construction is increasingly being used, but I do worry for certification and the sustainability of the forests and forest management. (Imme Groet, personal communication, November 23, 2021)*

Another associated obstacle is the *insufficient processing capacity and infrastructure along the timber construction production chain*. With increasing demands for timber in construction the capacities of the processing facilities also need to be capable to answer this demand. Facilities such as sawmills and timber factories need to be large enough to process the additional wood into timber and might not be well-suited for a sudden and exponential spike in demand.

> *When timber construction takes off the production chain also needs to be ready. My personal vision and fear is that this might not be the case, the production chain might not be ready for exponential growth. (Mark Beuving, personal communication, November 17, 2021)*

When the production chain has not been fully developed and its processing capacity is not able to answer the exponential growth in demand there could occur a shortage on available timber building elements on the construction site. This risk of unavailability of the timber building elements could slow down the material transition and adoption of timber as constructors would avoid this risk of the inability to deliver and therefore stick to conventional materials.

> *I expect that the biggest obstacle is going to be the producing capacity to have enough timber construction elements available, the timber construction materials necessary to build residential and non-residential buildings. (Jan Oldenburger, personal communication, November 16, 2021)*

In line with these obstacles of unavailability is consequently a *risk of substantial increases in timber building material prices boosted by a supply deficiency*. This is again closely related to forest management and timber processing capacities, but also emphasises the price impact of a sudden growth in demand and what it could mean for the cost of construction.

> *In regard of the ambitions in the Netherlands and Germany, in Noordrijn-Westfalen and Berlin for example, I wonder if there is going to be enough timber and if it is going to be affordable. (Wim Sturris, personal communication, December 2, 2021)*

Correspondingly *the costs of building materials and specifically the costs of timber building materials* are also seen as a major obstacle in the business-as-usual scenario. This is especially the case because initial costs of timber building materials are higher than traditional materials and therefore so are the initial costs of investment.

> *Timber compared to concrete demands roughly the same amount of materials. The costs of concrete is roughly 200 euro per cubic meter, timber currently stands at 500 euro per cubic meter, two and a half times as expansive. Looking at a residential building of 200 houses, and approximately a 30 meter span, your initial investment costs will be roughly two million euro more for timber compared to concrete, based on material prices. (Wim Sturris, personal communication, December 2, 2021)*

This often presents the first obstacle for construction developers who are primarily confronted with these high initial costs of investment. Experts explain that, when approaching housing corporations for example, these costs are often where most of the convincing takes place. Also, the experts explain that the initial costs of investments remain rather dominant in the assessment of the costs and the decision making process in regard of the utilized construction materials. The relatively high initial cost of timber is therefore recognized as a major obstacle.

> *Another point of attention is the notion of costs. The first reaction when convincing construction developers to work with timber, for example a housing corporation, often is: "what are the costs". This is because the initial costs of investments are slightly higher for timber construction. (Mark Kemna, personal communication, November 16, 2021)*

Also identified as a major obstacle in achieving the experts desired future within the business-as-usual scenario is the *unavailability of construction professionals, workers and contractors with the adequate knowledge and engineering capacity to work with timber building materials*. This obstacle aligns with the former obstacles as it is another example of an insufficiently developed aspect on the value chain. Without an available amount of timber construction professionals new construction projects would also remain relatively inaccessible. Even when timber resources and building elements are plentiful

available, timber construction professionals remain vital in the realisation of timber construction projects and their unavailability could therefore slow the material transition and adoption of timber significantly.

> *There have to be enough builders on the construction sites. In construction today there is a general shortage of personnel yet, professional builders are necessary for carpentry and the assemblance of prefabricated modules. Some constructors have been traditionally building with concrete for years and have invested in their own concrete mixer for example, they would have to adjust and this takes time. Also, they would be more willing to invest in this adjustment if they would have some more confidence in the continuity of the demand for timber construction. (Irma Thijssen, personal communication, January 11, 2022)*

This is particularly the case for construction workers who are experienced in working with engineered wood products such as cross laminated timber. These new innovations have been emphasized for their substituting potential however they require a new set of skills and traditional construction workers need to be retrained in these new systems.

> *Apparently, there is a shortage in the amount of constructors who have knowledge about LVL and CLT and know how to work with these products. This seems to be an issues, adequate amounts of engineers who have been schooled in timber construction systems. (Maarten Willemen, personal communication, December 2, 2021)*

3.2.2 Opportunities

The most quoted opportunity in accomplishing the desired future within the business-as-usual scenario is the *integration of carbon pricing and carbon storage in construction policy and regulations*. Most of the experts explain that the primary advantage of building with timber-based materials is the inherent characteristic of sequestering and storing of atmospheric carbon in wood, and consequently in timber. This specific property in timber production results in very low or even negative carbon emissions contrasting the highly polluting industries behind the production of mineral-based building materials. Experts therefor expect that carbon pricing and the encouragement of carbon storage in long-lived products such as housing, could be a major opportunity to the substitution of as much fossil-based construction materials with timber as possible within technological, sustainable and rational boundaries in a business-as-usual scenario to 2050.

> *The CO2 taxations are going to have impact, we cannot avoid those. When CO2 emissions of materials are being accounted for in pricing the price differences are going to be smaller. (Wim Sturris, personal communication, December 2, 2021)*

As this price difference is currently recognized as one of the major obstacles in the large-scale application of mass timber construction, CO2 taxations could consequently become a major price incentive for the use of timber and other biobased construction materials. This is especially the case because timber and other biobased materials are often associated with very low and even negative CO2 emissions in the production process. This could, consequently, result in a competitive advantage for timber over conventional materials making it the more attractive material based on pricing.

> *If CO2 pricing schemes are seriously implemented it would be an incredible boost for timber construction. (Maarten Willemen, personal communication, December 2, 2021)*

This is not only recognized as a major opportunity and stimulation for timber construction, it is also recognized to simultaneously discourage the use of abiotic building materials with large carbon emitting impacts. The production of conventional construction materials such as steel and cement are known to be one of the most CO2 intensive industries in the world. Incorporating this through CO2

pricing mechanisms would therefore have a significant impact on the material price and could, opposite to timber and other biobased materials, result in a significant competitive disadvantage.

> *Another reasonably well-known opportunity is the carbon sequestration. We all talk about its potential for the construction sector when this is rewarded more and how it could discourage the use of traditional materials through pricing mechanisms. This is also one of the attention points in our project, to lobby for its adoption in legal and regulatory framework. (Mark Kemna, personal communication, November 16, 2021)*

Together the financial incentive to use biobased materials and discouragement of the use of CO2 intensive conventional materials could contribute significantly in the decision making process of construction developers. This could be achieved through the adoption and acceleration of carbon taxations and pricing schemes in construction materials and their production industries. When biotic materials such as timber become economically more attractive than conventional materials this also solves a major initial obstacle and could potentially boost the adoption of timber substantially.

> *I believe the CO2 taxations are going to play an important role, especially when they will be accelerated. this would make the advantages of biobased materials financially visible in the construction budgets. Currently constructors sometimes choose to use abiotic materials over biotic materials, in for example isolation, to reduce the construction costs, this would no longer be the case. (Lidewij Lenders, personal communication, January 13, 2022)*

One of the regulations that has been most often referred to in all the interviews is the *"Milieuprestatie Gebouwen"* or MPG, a mandatory criterion indicating the environmental performance of the materials used in a construction project. The MPG must be included in every construction permit's application and as such defines the environmental standard for a construction project. The MPG is therefore recognized as a vital instrument in the evaluation of timber-based building materials however, the MPG criteria currently do not include the biogenic carbon that is stored in timber. Nonetheless, experts express the great potential of this regulatory instrument when the environmental impact of timber building materials compared to conventional building materials are fairly evaluated.

> *One of the turning points – of which we hope to see it become reality – is the valuation of stored CO_2 in biobased materials. When this feature is included in the calculated environmental performance of buildings (MPG) it would contribute significantly to the use of timber and other biobased materials. (Eric de Munck, personal communication, November 9, 2021)*

The experts explain that the revision of this regulation has been taken under consideration by the Dutch Ministries who are responsible for it functionality. In the meantime, different timber construction projects have already been demonstrating the low MPG score that can be accomplished when working with this material and by doing so indicate its sustainable potential.

> *What I have heard from the sector is that the MPG is considered a very important policy instrument. The ministry of interior and kingdom relations is currently investigating the possibility to better include the stored CO_2 and re-utilizing features of timber product in this policy instrument. There are, however, increasing amounts of exemplary projects that demonstrate the low MPG timber buildings can conform. (Irma Thijssen, personal communication, January 11, 2022)*

Others however indicate that some specific barriers remain actively involved in the integration of these biotic materials and their carbon capturing and storing capacities. Stressing that the strong position of established industries in the construction sector aim to prevent such adaptation from being made as it would be disadvantaging their interests. This underlines the importance of a fair and unbiased process.

> *The MPG (environmental performance buildings) has been developed as policy tool to cover the hidden costs of building materials. In this tool, just like any other, it is important that all information and basic assumptions are correctly represented. The current challenge is to achieve the fair and accurate representation of biobased materials in this tool. Accounting for the CO2 stored in these materials is one of the primary challenges. (Lidewij Lenders, personal communication, January 13, 2022)*

A second major opportunity to accomplish the desired future within the business-as-usual scenario is *the understanding and growing awareness of the advantages of timber construction* amongst consumers, constructors and policy makers. Experts explain that they still spent a lot of time laying-out the advantages of working with timber regarding climate change, construction costs and engineering compared to conventional materials. They believe that enhanced awareness could provide timber construction with a competitive advantage over conventional materials. This is demonstrated by the concept of Total Cost of Ownership (TCO) which specifies the cost of a construction project from start to end. This concept allows investors and constructors to look beyond initial investment costs as it also considers transport, construction speed and maintenance.

> *It all starts with the understanding of the housing corporations and this is where we really feel that we should begin. We are actively working on a Total Cost of Ownership tool with which we hope to inform the housing corporations that construction costs are much more nuanced than the initial costs of investment, including also the operational and maintenance costs for example. (Mark Kemna, personal communication, November 16, 2021)*

The MPG which has been mentioned before is also recognized as a vital tool in the availability of information and its potential to create more awareness of the poor environmental performance of conventional building materials, especially compared to substitutional biotic materials.

> *Another great opportunity is the fact that we have to reduce our CO_2 emissions and we know how to translate this to CO_2 storage in terms of construction stored carbon and through the updating of the MPG. This is something that we aim for with Gideon because it is an opportunity to specify the material features and create awareness about the use of fossil-based resources in conventional building materials like concrete and stone, and the associated CO_2 emissions. (Jetske Thielen, personal communication, November 23, 2021)*

Some advantages of specific innovations in timber construction have also been repeatedly emphasised. The most important of which is the ability to re-utilise timber building elements, this is particularly the case for CLT panels. This is recognized as a valuable feature because it aligns with the development of the circular economy, aimed for by the Dutch government.

> *You are better of applying a building element that might initially be slightly more expansive of which you know for sure that you can reutilise it at the end of operationality, CLT building elements are very appropriate in this sense. It is possible to disassemble the large CLT building elements, basically reversing the construction process at the end of the operational use of a particular building. The panels return to the factory where they can be dismantled even further, allowing the complete reutilisation of the timber segments. In this regard, especially the CLT building elements become very interesting for lifecycle assessments and consequently for sustainable investments. (Wim Sturris, personal communication, December 2, 2021)*

Besides the previously mentioned CO2 storing and re-utilizing features of these timber panels is the perceived quality of the living environment which is often experienced as very comforting. This is yet another quality that is not included in the value assessment and pricing of these products.

> *I work a lot with CLT which is a qualitatively valuable product that feels really reliable. The price of the resources in this product is higher than for example limestone, however, the material*

> *does contribute to a comfortable living environment and stores CO2. These are typically the advantages that are not taken into consideration of operational costs. Additionally, these panels are very appropriate for reutilisation, allowing them a lifespan surpassing 50 years, which has not been included in the MPG. (Lidewij Lenders, personal communication, January 13, 2022)*

Noteworthy in the above is that the experts emphasise the carbon storing capacity of the CLT panels in addition to the re-utilisation possibilities, outlining the impact carbon pricing could have on the price and value of these timber building elements.

3.2.3 Measures

The first measure that has been identified by the experts as an important step towards the accomplishment of the desired future within a business-as-usual scenario *is the establishment of functional and fair carbon regulations and carbon pricing.* Especially the updating of the criteria used in the MPG has been expressed as a necessity in the near future.

> *Including the construction stored carbon in the MPG is definitely a very important measure. I believe that updating the MPG is among the most important measures. (Jetske Thielen, personal communication, November 23, 2021)*

Experts explain that this has been emphasised before and not a lot of progress has been made in this regard yet. To update the MPG also its fundamental Life Cycle Analysis calculations need to be addressed in such manner that they include all the appropriate carbon sequestering and storing capacities of the biotic materials. Experts express that this step has been prolonged to long and that the acceleration of this updating process is necessary in a recently near future.

> *Currently we actually are in a business as usual scenario. Last year the request has been made to update the MPG and the LCA-calculations to include the CO2 storing properties of materials, yet the ministry does not believe it is her responsibility to quickly address these requests. Hence, they have made a tender request for a research looking into the specifics, however it does not seem like there has been a lot of progress. (Sandra Nap, personal communication, December 21, 2021)*

The accurateness of the MPG as a policy tool is very important for its functionality and it has also been recognized that this instrument is necessary to dismiss the issues of high resource prices. The role and responsibility of policy makers in this transition is therefore again underlined. In this instance particularly for the facilitation of law and regulatory frameworks that incentivise the sustainable use of, and use of sustainable resources. This is deemed necessary by experts to overcome other obstacles such as the initially high costs of alternative biotic materials such as timber.

> *The current issues of investment costs, which are mostly articulated by developers, could be resolved when policy tools are much more focussed on the use of the most sustainable materials. Therefor it is a very important step and the policy makers are the key players to address this in legal and regulatory framework. Therefore I believe that the first step is adjusting the legal and regulatory frameworks, this would significantly speed up the process. (Mark Kemna, personal communication, November 16, 2021)*

These regulations in the first place allow the fair evaluation of environmental impact of materials but is also identified as an important incentive for investors to include sustainable and circular buildings in their portfolio. Experts explain that the valuation of those assets and properties that are part of large investment portfolios are based on these regulations. The fair inclusion of environmental performance of timber and other biotic materials would make it a lot more attractive for investors to include them in their investment portfolio because they can translate the environmental performance into value.

We are currently not rewarded in the valuations and in the different environmental standards for the application of timber, the MPG and the GPR for example. This is important for us because our properties and investments are valued by the appraiser based on these environmental standards. We cannot translate the use of timber into value when the sustainable certificate is not accredited to us. Therefore the valuation of timber in these standards is a necessary step, and this is where you need the government. (Ingrid Hulshoff, personal communication, November 9, 2021)

When the administrative frameworks that have been set by the government – the calculated criteria such as BREEAM, MPG, LCA's and others – allow the fair assessment that timber deserves, investors and housing corporations will follow. (Maarten Willemen, personal communication, December 2, 2021)

These financial actors are recognized as very important stakeholders because they decide over the capital means necessary for constructors and architects to deliver their product. This is also unmistakably decisive in the form and execution of construction projects and directly impact the selection of building materials. Making it more attractive for financial stakeholders to invest in timber construction projects could result in a substantial capital flow with the potential to significantly contribute to the experts desired future.

Currently there also is an issue with the banks and pension funds and the other construction investing parties in this country. Because they are decisive in the direction that is chosen however, they tend to be conservative because their main objective is to financially profit from their investment and they are only just learning about these different developments. Most of all they focus on the potentiality of a business case before they invest and they are therefore more likely to invest when CO_2 pricing schemes are in place. (Maarten Willemen, personal communication, December 2, 2021)

Some experts explain that it is also worthwhile to attract different and new financiers towards timber construction projects. They emphasise the potential of stored CO2 in construction as a completely new but potentially profitable investment opportunity and explore other similar possibilities related to biobased materials. Fundamental to this financing strategy is the prospect that carbon stored in construction could be translated in tradable emission permits or other carbon pricing schemes that could change valuation perspectives of biobased buildings.

Traditional parties finance construction projects in a traditional manner based on the lowest price of purchase. This is an issue because they are conservative about their business case conditions and therefore do not adjust them to circular investments. For that reason we aim to add a different kind of financier early on in the process, allowing them to support the high ambitions in regard of biobased construction. One example is the construction stored CO2 value which is likely to become only more valuable in the future. (Sandra Nap, personal communication, December 21, 2021)

This also corresponds with the need to *establish a stable and continuous market for timber and engineered woods*. Something that can be achieved with the creation of a continuous flow in demand and supply of resources, another key measure that has been identified. This continuity is needed to stabilize the recent price fluctuations and to allow constructors and investors the confidence to start new construction projects.

What is necessary is the guaranteeing of a reliable supply chain of the engineered wood products as well as solid wood resources and the stability of their price. This is crucial for the purchasing confidence of developers, especially since last year's demonstration of what a spike in demand could do to the supply chain. (Wim Sturris, personal communication, December 2, 2021)

Different steps have been commented on to achieve this continuity of supply and demand. First of all, construction companies need the *assurance of future projects*. Experts explain that without a certain level of security the risk to invest in these new supply chains is often regarded to high. The dedication of housing corporations, provinces or metropolitan regions to commit to timber construction can therefore be regarded as an impactful measure, allowing constructors to secure future projects and make the investments that are necessary to realise high quality timber construction projects.

> *On the one hand you need enough suppliers and on the other hand a continues flow of construction requests. For instance, the participants of the Green Deal Houtbouw in the MRA, the Metropolitan region Amsterdam, who have agreed to execute 25% of residential housing in timber in the forthcoming 10 years. So, there is a need for requestors that choose timber construction. This could be the municipalities, housing associations or project developers, for example. (Irma Thijssen, personal communication, January 11, 2022)*

A more specific role could be played by the national government in their demand for and management of governmental buildings. Being a major requestor of construction work the government could also provide more security to construction companies by dedicating a percentage of their requests in timber or set a standard for the use of biotic materials. One expert explained; they could follow the example of other European governments, such as France.

> *I believe a similar pathway could be followed as for example France. Which means that the national government sets a certain minimum volume for the buildings that are under her own management or construction request. The government building agency could than state that the construction of all government buildings should at least include a certain amount of timber. I believe that could be a start. (Eric de Munck, November 9, 2021)*

Another step to achieve continuity in supply and demand is the *development and expansion of the supply chain*, this is especially the case for the processing capacity of sawmills which have proven to be somewhat inadequate in previous years. The sawmill facilities are one of the first steps in the value chain of timber construction and therefore automatically impact a substantial part of the whole chain when it lacks the processing capacity needed to attain for the demands. Different global developments have disturbed the value chain last year and allowed the price of timber materials to skyrocket. This underlines the importance of the development of these primary facilities to maintain stability in the value chain and a balanced price.

> *What is necessary to allow the development of timber construction is the establishment of continuity in timber production, especially the role of sawmills has been shown to be essential in the global supply of timber resources. Therefore I believe there should be more sawing capacity in Central- and Northern-Europe and we need to develop the continuous flow of timber to guarantee that supply and demand are balanced against a reasonably stable price. (Wim Sturris, personal communication, December 2, 2021)*

Overall, the Dutch national government has been identified as the key actors in the development of mass timber construction and the accomplishment of the desired future in the business-as-usual scenario. Their role in the facilitation of a fair and equal competition based on accurate information about environmental impact in construction regulations is recognized as the most important measure. Also, in relation to the climate change mitigation goals set in the National Climate Agreement and the government's goal to reach a completely circular economy in 2050, it is being recognized that the adoption of carbon pricing schemes would substantially impact the use of more sustainable building materials like timber. Finally, the government has also been identified as a major stakeholder on the demand side with the potential to dedicate the use of mass timber in state construction projects, setting an example and allowing a continuous demand for construction companies.

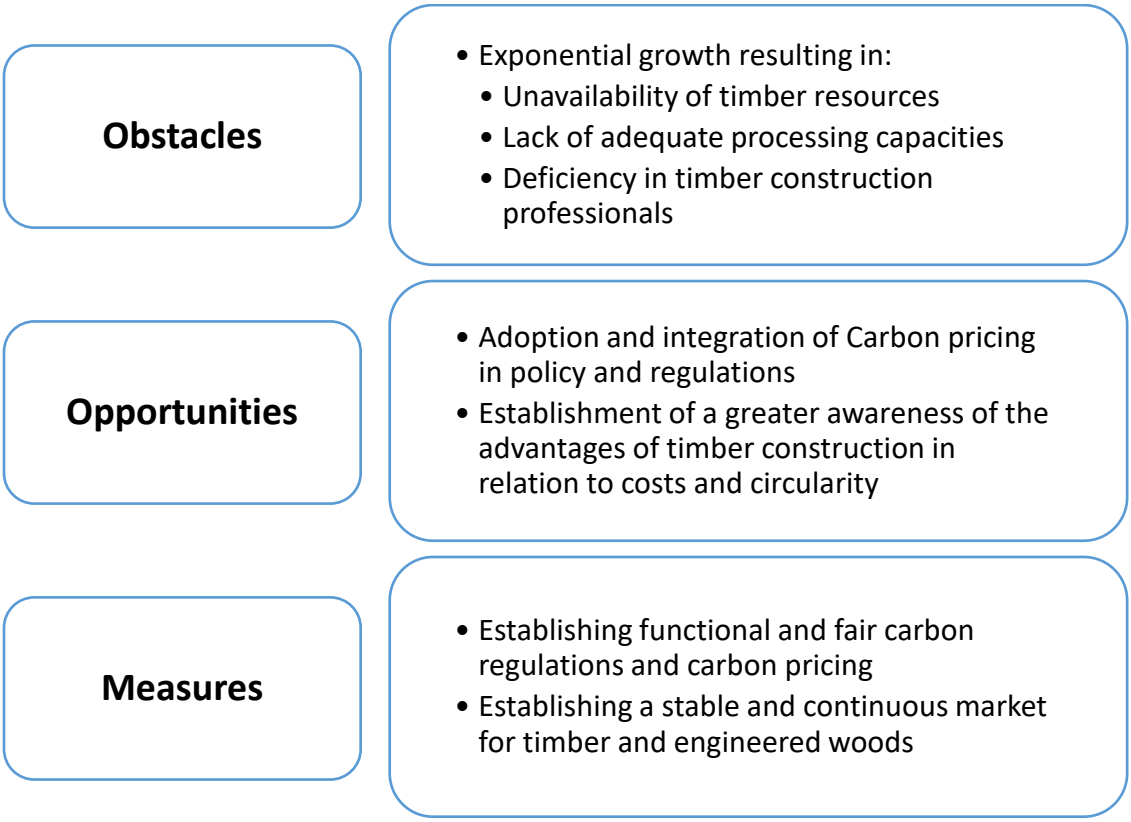

Figure 12: Overview of Findings in the Business as Usual Scenario

3.3 The Warm Scenario

Following the Business-as-Usual scenario experts either explored the Warm or the Paris scenario. Based on their position in the production chain of mass timber construction, ranging from foresters to constructors, the experts have been divided over these two scenarios. In the following section the findings from the expert explorations within the Warm scenario will be described. In this scenario the experts were again asked for their envisioned obstacles, opportunities and fitting measures to attain the desired future outcome for mass timber construction. The first apparent difference with the Business-as-Usual scenario is the increased difficulty for the imagination of this formerly unknown situation and consequently their imaginative capacity to formulate obstacles, opportunities and measures accordingly. Nevertheless, experts were able to step outside of their domain of knowledge and give their personal perspective on this possible outcome and the impact it could have on the desired future.

3.3.1 Obstacles

The most mentioned obstacle in the Warm scenario is the *unavailability of timber resources and timber-based building elements*. This obstacle is explained in relation to different expected consequences the Warm scenario could have on forests and forest management. Particularly the occurrence of more extreme climatic events as a result of rapidly advancing climate change, such as droughts, storms and other ecological disturbances.

> *There exist multiple risks for wood production. There could well be a shortage of useable wood because of the environmental impact of climate change on our forests. Because these forests are often homogenous stands, changes in the climate and its unpredictability could have significant impact the quality and health of the forest and simultaneously affect the biodiversity. (Sandra Nap, personal communication, December 21, 2021)*

Additionally, the neglect of climate policy and a focus on sustainability in the Warm scenario could have direct impact on forest management practices. Sustainable forest management practices are fundamental to circular timber production. Without this focus on sustainability there would be a serious risk of overexploitation and the depreciation of global forest ecosystems. Climate policies are essential in this because they are necessary to reduce climate change and consequently prevent high ecological stress and frequently occurring natural disturbances that damage ecosystems. When these are neglected a rise in global warming and climate change impacts could have serious consequences for standing forests globally.

> *I expect that due to the acceleration of climate change the forests will also become less productive. Additionally I expect that the focus on sustainable forest management and the assurance of long term wood production becomes neglected. Other issues would become more dominant in policy and subsidies for forest management, for example, could be consequently reduced. Hence, I expect that the availability of timber would be much lower and certain necessary innovations to develop this sector would not be realised. (Jan Oldenburger, personal communication, November 16, 2021)*

A second major obstacle in the Warm scenario is a combination between a *lack of regulations and sustainable incentives and the inherent conservative character of the construction sector*. As has been described, in the Warm scenario the government abandons its focus on climate change and therefore does not follow through on carbon storing and pricing regulations nor other sustainable incentives. These have been recognized as vital in the development of mass timber construction and the achieving of the desired future outcome in the business-as-usual scenario and apparently remain a major sphere of influence in the Warm scenario. In combination with a sector that is known to be very conservative in their innovations and their changeability this shortcoming is recognized as a major obstacle in the Warm scenario.

> *Currently there is some legislation on environmental and political goals, as well as intrinsic motivation of companies. When this is lost it would become a race to the bottom where only the cheapest chemically produced materials will be used. I do not think that legislation is going to be very impactful in your scenario Warm, because the government does not aim for a reduction in environmental degradation. I believe that in this scenario you can forget about the MPG, because all the incentives to use it are reduced to zero and the only incentives to use certain materials will be its price. (Imme Groet, personal communication, November 23, 2021)*

The conservative character of the construction is inherently and traditionally connected to the sector. Constructors are responsible for safe and durable housing and because of this they are reluctant to experiment and innovate with new systems of building. This makes the sustainable transition of the construction sector a challenge overall and the adoption of timber construction as a new possible system recognized as rather drastic.

> *The propensity to change within the sector remains an issue. The construction sector is inherently a very conservative and traditional sector because changes can have significant impacts and could quickly result in a lot of damage. I believe that when you approach a random constructor in the Netherlands, approach 95% percent of them, and you will find that they are not concerned with sustainability. Constructors in the Netherlands have plenty of work as they are and therefore do not see why they should change. Constructors often are used to working with conventional materials and when confronted with new innovations they tend to react defensive, these changes are not embraced because the unknown is unappreciated and this makes the sector very unwilling to change. (Wim Sturris, personal communication, December 2, 2021)*

The conservative character and the40nwillingnessss to change within the construction sector goes at the expanse of autonomous innovations and without the necessary motivation it seems like the sector would not change their course effortlessly. This is particularly expected when the resource price for timber remains higher than the conventional materials.

3.3.2 Opportunities

The most mentioned opportunity in the Warm scenario is by margin *the growing awareness of climate change and the realisation that something has to change.* In the Warm scenario climate change impacts become increasingly visible because of a global shortcoming in sustainable innovations and climate policy and the long long-lasting dominance of fossil-based energy and resources. The experts address that the growing environmental awareness in society could result in a higher demand of sustainable products and solutions in the future, therefore forcing industries to change their products and innovate their production processes.

> *Everybody recognizes that something is going on, this is especially the case for consumers like you and me who realise that something needs to change. This is going to have an impact because the growing awareness of these consumers results in a demand for new and sustainable products and the sector is obliged to deliver. The sector is defensive and conservative but I believe we need to look at it holistically and acknowledge the significant growth of societal awareness. (Wim Sturris, personal communication, December 2, 2021)*

Experts also emphasise that when societies are repeatedly disappointed in the way governments address certain issues, such as climate change, they are more likely to demand a change and have their voices heard during protesting actions, for example. They underline that societies voice is very powerful and capable of forcing governments into a different strategy when this is believed to be necessary. Within the Warm scenario, experts believe that societies are very aware about climate change impacts and would start protesting against the negligence of environmental policy by the government and demand a change in strategy.

> *I believe that the voice of the people becomes even more important in deteriorating situations. I believe this is inherently connected to each other because disappointments always results in protests. When global economic and climatological conditions deteriorate that much it will undoubtedly result in protests demanding a turn in policy and strategy. In your scenario Warm the voice of the people therefore becomes even more important. (Mark Beuving, personal communication, November 17, 2021)*

A second opportunity that is recognized within the Warm scenario is *the inevitable decline in availability of fossil-based resources that are currently used for the production of conventional building materials and energy.* The experts anticipate in this scenario, where fossil-based resources remain dominant in energy production and construction, that these limited materials become more scarce and therefor more expansive. This concerns the availability of mineral resources such as sand and iron, but also the availability of fossil fuels that power steel and cement production. Increasing scarcity could drive up the price of energy and resources for these conventional construction materials without drastically impacting the price of biotic construction materials. Biotic materials are naturally produced and their production is powered by the sun, therefore these materials will be less affected by rising energy prices. This could result in timber and other biotic materials to become more competitive with conventional materials or even more economically attractive.

> *If we continue with concrete and steel this will result in the exhaustion of the Earth and speculation already exists on shortages of mineral resources, even sand. The energy prices are already increasing drastically and if there is one sector who is going to experience the consequences of this it would be the conventional construction sector, much more than timber*

obviously. This can be regarded as an opportunity, the increasing costs of production of conventional industries making timber the more economical choice. (Mark Beuving, personal communication, November 17, 2021)

Also, *specific innovations and treats of mass timber construction* are seen as potentially economically competitive in the Warm scenario. These are often associated with the industrialisation of the construction sector and underline the assembling advantages of engineered timber building elements such as prefabricated modules. Additionally, timber construction can bring down expanses in areas where the soil foundations are unstable or unsuitable because of its relatively light weight compared to steel and cement. This would allow the construction of buildings with less foundational requirements and effectively reduce the overall costs of the project.

When you look at price control you can recognize that prefab timber construction is much faster than conventional construction and this reduced construction time really brings down the costs of a construction project. This is also true for some areas in The Netherlands where the soil is unfit for heavy construction. Using the much lighter timber-based materials instead of conventional materials in these areas could therefor significantly reduce the foundation costs. I believe that timber construction could still win based on these characteristics. (Imme Groet, personal communication, November 23, 2021)

Notwithstanding the unbeneficial conditions that are part of the Warm scenario the experts recognized that some specific developments could still be enough to encourage the necessary expansion needed for mass timber construction to attain their desired future.

3.3.3 Measures

One of the measures that is emphasized for the Warm scenario as a potential step to achieve the desired future is *the adoption of a different approach to the perception of cost of construction*. The construction process and all associated cost and expanses might not accredit the stored value of a building and its materials, experts explain that a more holistic perspective could be in the advantage of mass timber construction projects taking into consideration the value of materials that can be re-utilized.

The measure I would be looking for is to emphasize the total cost of the entire lifespan of a material, this incentivises durability and quality and derives the focus from initial purchasing price. Currently the operating costs are seen independently from the total costs but I believe the perspective on costs should be more holistically, this would benefit the use of biotic resources and make it economically attractive. (Imme Groet, personal communication, November 23, 2021)

A second measure that is identified in the Warm scenario is the need to *Provide complete and accurate information to actors and stakeholders taking part in this transition*. This aligns with the identified opportunity that emphasizes the potential of increased environmental awareness among society. The distribution of information is especially important for decision-makers that have an impact on the development of mass timber construction. One of those key decision-makers are policy makers who for obvious reasons need to have all the accurate and complete information available.

I find it increasingly striking that policy makers are not informed about these developments. Substantive knowledge on the relation between the energy transition, the meaning of circularity and the contribution of CO2 emissions by the construction sector. We are actively engaged in the spreading of information and raising of awareness on these developments and we still encounter numerous occasions where people do not know the relationship between circular and biobased. There remains a lot of room for improvement because it is not right that people are uninformed. (Sandra Nap, personal communication, December 21, 2021)

Besides policy makers, big construction companies also represented a powerful stakeholder in the development of mass timber construction. Those who dominate a large market share could substantially impact the innovative environment within the sector and through the presentation of information and new opportunities these stakeholders could be inspired to rethink their own practices. Informing especially those stakeholders that are in a position to substantially contribute to the direction and future of a sector or industry as a whole is therefore recognized as an important measure. This can be accomplish by the presentation of new and innovative ideas which consequently contributes to the achievement of the desired future of the experts.

> *We need to change together, and I believe this is possible. Last year I was invited to give an inspiration presentation at BAM. I presented this in front of a room filled with traditional concrete constructors. Afterwards they approached me enthusiastically about what they have learned about timber, this was a very surprising experience for me. The BAM has really done a good job, informing and inspiring their constructors to become intrinsically motivated. I believe this is the way to accelerate a transition. (Lidewij Lenders, personal communication, January 13, 2022)*

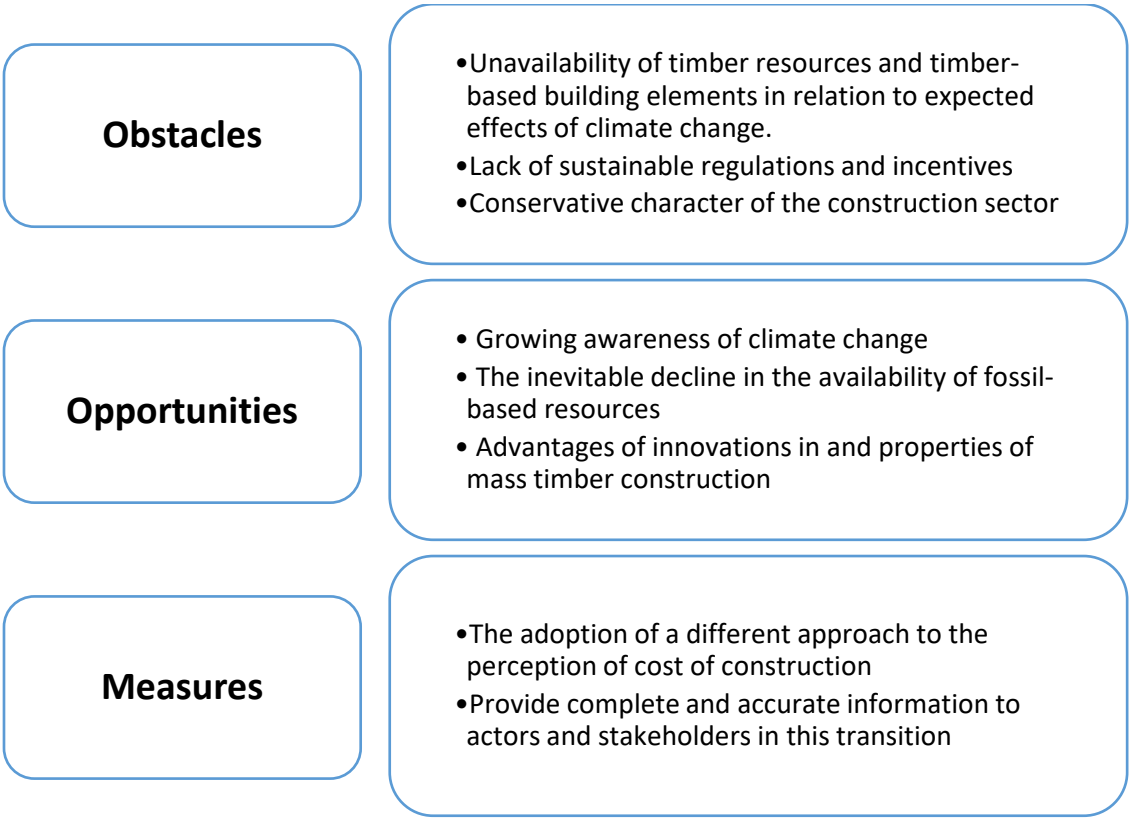

Figure 13: Overview of Findings in the Warm Scenario

3.4 The Paris Scenario

In the Paris scenario the experts were again confronted with a possible future outcome. This specific scenario is optimistic compared to the two that have been explored in the above section. This scenario demands the experts to imagine a future in which the goals formulated in the Paris Climate Agreement are accomplished in 2050, a future that most of the experts thought more unlikely than the former and less optimistic scenarios. This meant that the experts were again challenged for their imaginative capacity to think beyond what they have anticipated for the future themselves and come up with obstacles, opportunities and measures encountered in the development of their desired future for

mass timber construction. This seemingly resulted in a noticeably less amount of identified obstacles, opportunities and measures and included detail compared to the Business-as-Usual scenario. Yet, in this the results of the Paris scenario closely resemble those of the Warm scenario and just as well provide another insightful expert perspective in the exploration of a possible future.

3.4.1 Obstacles

The main obstacles in the Paris scenario expressed by the experts relates to the expectation of a steep increase in mass timber construction. These obstacles are *issues in the supply of timber resources and availability of experienced timber construction professionals*. In the first place the increase in demand of timber resources could have a negative effect on the management practices of the European forests and risk exploitation of those ecosystems.

> *Back in the days timber was regularly used in construction and in reality we are heading back in that direction. This is great, however, when you carry it too far and lack the sustainable utilization of the forests you risk overexploitation. It is easy to say that timber is a sustainable product, but for this to be true you have to guarantee that forests are managed sustainably and in such manner that future generations are also capable of meeting their own needs. (Henk Wanningen, personal communication, December 23, 2021)*

The sustainable principles mentioned here are recognized as of vital importance for the future availability of forest resources and the protection of forests overall. They have to be maintained to prevent overexploitation, forest ecosystem deterioration and the potentially associated collapse of whole ecosystems. However, these sustainable practices prescribe fundamental limits to production and harvesting and therefor have a direct impact on the availability of timber.

> *When the true value of timber is recognized a surge in demand would logically follow. Maintaining the sustainable principles of forest management means that trees are selectively cut for wood and this could result in times where timber supplies are limited. (Mark Kemna, personal communication, November 17, 2021)*

This is followed by the expected issue of *insufficient and unexperienced timber construction professionals*. A steep increase in the demand for mass timber construction could result in a hurried transition of conventional builders to timber-based builders with the risk of inadequate transmission of knowledge and skills to deliver reliable and qualitatively sound buildings.

> *One of the obstacles I recognize is timber construction expertise, people in the sector need to be retrained, masons need to be transformed into carpenters and other disciplines that work and think in different ways. Currently people with expertise are hard to come by and this also enhances the risks of poorly build constructions. When people pretend to be experts, even though they lack the qualifications, they risk making serious construction errors. If this happens too often it could also affect the material's reputation, resulting in a shift away from those materials that are no longer trusted. (Michel Post, personal communication, December 17, 2021)*

Another obstacle is highlighted in relation to the limited amount of timber construction professionals, being *the mineral tradition of architecture and building engineering education programs*. The current lack of university chairs specialized in alternative construction materials is recognized as a potential issue in relation to the accomplishment of the desired future within the Paris scenario. Currently there already exists a shortage in construction workers for conventional construction projects to be carried out in the Netherlands. With a surge in demand for timber construction projects a deficiency in construction professionals could occur, particularly for those who have experience in timber

construction. This issues is associated with the lack of university or vocational education programs that address alternative materials and new innovations.

> *There is a need for more professionals with adequate knowledge. The University or Higher Vocational Education programmes should deliver new professionals, yet there is a lack of interest in timber construction and consequently a limited amount of students graduate with the corresponding expertise. (Eric de Munck, personal communication, November 9, 2021)*

This is illustrated in the following anecdote, underlining the total neglect of timber construction possibilities in engineering educational programmes.

> *Someone once told me that they had to explain an engineering student during his internship that it is possible to build houses with timber and not only garden fences. He just did not know, and this is striking for the educational programme and their rather traditional perspective on construction materials. (Mark Kemna, November 16, 2021)*

3.4.2 Opportunities

The most mentioned opportunity to achieve the desired future within the Paris scenario is *consumer behaviour and awareness.* Experts identify this as a potentially very impactful opportunity, they explain that in a scenario where the government concentrates its attention on climate change adaptation and mitigation policies it is likely that consumers will follow their example. Also, because of the strong and healthy economy this scenario is associated with, experts believe that consumers would be better capable and willing to spend more on sustainable products, therefore creating a strong demand for sustainable products on the market.

> *I also think that consumers are becoming increasingly aware and demand more sustainable products. Consumers do, however, often have the habit to desire the things that they know over those they do not know. This of course is a fairly well known phenomenon but I believe that there will be more room for campaigns that present the impact of biobased and perhaps timber construction particularly. This could again accelerate timber construction. (Jan Willem van de Groep, personal communication, November 18, 2021)*

A more commonly held awareness of sustainable products and an increase in its demand is also expected to impact the behaviour of companies and their shareholders. Experts think that companies themselves will represent this awareness because of their sense of responsibility as well as the experienced need to follow this trend.

> *You can recognize that the sustainable movement is starting to accelerate. I believe that companies play a large role in this, actually enhancing sustainability in the economy and construction. Hopefully this also stimulates the government to become more ambitious than they currently are. (Henk Wanningen, personal communication, December 23, 2021)*

The growth of economic prosperity in the Paris scenario is expected to benefit sustainable forest management and the certification of forest globally as consumers are more likely to dedicate a proportion of their income to sustainable products. In combination with countries around the world following up on the Paris agreements forest ecosystems become even more valuable, therefore a significant growth is expected in sustainable management through forest certifications.

> *I expect that with increasing wealth people also change their consuming behaviour, especially in relation to forests and sustainable products. We at FSC are currently protecting only a small part of the amazon region in Brazil which is possible because of the timber demand from Europe. When Brazilians decide to start using more timber in a sustainable way, because they are economically capable of making different decisions, it would be a great impulse for certification and forest protection. Hence, when governments become more stringent in their environmental*

ambitions because of the climate agreements it would be very positive for timber construction. I believe that on average climate agreements and global economic prosperity would therefore have a positive impact on forests as well as timber construction. (Mark Kemna, personal communication, November 16, 2021)

Another opportunity that has been identified is *the expansion of industrialized building innovations such as the prefabrication of timber modules*. Currently major building companies in the Netherlands are investing in these innovations and experts believe that within the Paris scenario these investments could result in a rapid expansion of this new industrialized building method.

I think that the biggest opportunity for timber construction will be the industrialization of the construction sector. It is obvious that timber construction really profits because of this, Bam and Heijmans are investing in timber construction factories with high degrees of industrialization for instance. I believe this will accelerate timber construction as well. (Jan Willem van de Groep, personal communication, November 18, 2021)

In these opportunities it seems like a larger role has been dedicated to the market and the impact of consumer behaviour compared to the opportunities in the previous scenarios. Also noteworthy is that the awareness of sustainable products among consumers, society and the industries is again regarded as a large opportunity for the future. This current trend that is recognized by the large majority of experts is expected to grow even more strongly and become even more important.

3.4.3 Measures

One of the measures that has been more frequently mentioned by the experts is the *facilitation and improvement of available knowledge, especially in regard of stored and emitted carbon.* The experts identify this as a significant measure because they fear that companies who do not necessarily share the sustainability principles could deceive consumers by greenwashing their products or cleverly making use of regulations that remain inadequately informed. This could again result in unfair competition between companies who do follow the sustainability principles and those who solely claim to do so.

What I hope for is more transparency in the available data, especially in regard of the amount of stored CO2 and the genuine sustainability of a product. This information currently is not transparent and this allows companies and industries to make their products look better than the are in reality. This is of course some sort of greenwashing practices and this really needs to be looked at and directly related to this is the environmental database. (Michel Post, personal communication, December 17, 2021)

Keeping an comprehensive and up-to-date database about the carbon storing and emitting properties of the conventional and more innovative materials is described as a key measure to *prevent companies from misleading consumers through greenwashing practices*. The National Environmental Database has been created for this specific purpose yet currently remains outdated and incomplete with regard to timber and other biobased materials. Because of this imperfect system, companies with good intentions are sometimes forced to work with less sustainable materials.

The legal and regulatory frameworks in the Netherlands are founded on the environmental database which is incomplete. Many products that we, the ecological architects, try to implement are currently scoring poorly on their environmental assessments, simply because they are not included in the system. This means that we are forced to choose an alternative product that in reality performs worse, solely because the database is incomplete. (Michel Post, personal communication, December 17, 2021)

In line with these measures is the idea that within the Paris scenario *regulations that are currently out of place, such as the MPG, should finally be adapted to represent timber and other biobased materials more accurately*. In relation to this expectation, experts claim that this regulation could again be used as a good criteria for the carbon footprint of a construction project through the adoption of stricter standards. Also, in this scenario the experts believe there should be more room for encouraging policies and financial incentives as the government is dedicating more resources to climate change adaptation and mitigating policies.

> *It can be expected that when the Paris climate agreements are strictly followed countries would also have to stimulate the sustainable development and transitioning of the construction sector. This would also mean that countries would implement encouraging policies to stimulate the development of timber construction. This could be done through subsidies on the use of biotic materials like timber, or lowering the MPG score, making timber the only possible option left capable of attaining that score. (Mark Kemna, personal communication, November 16, 2021)*

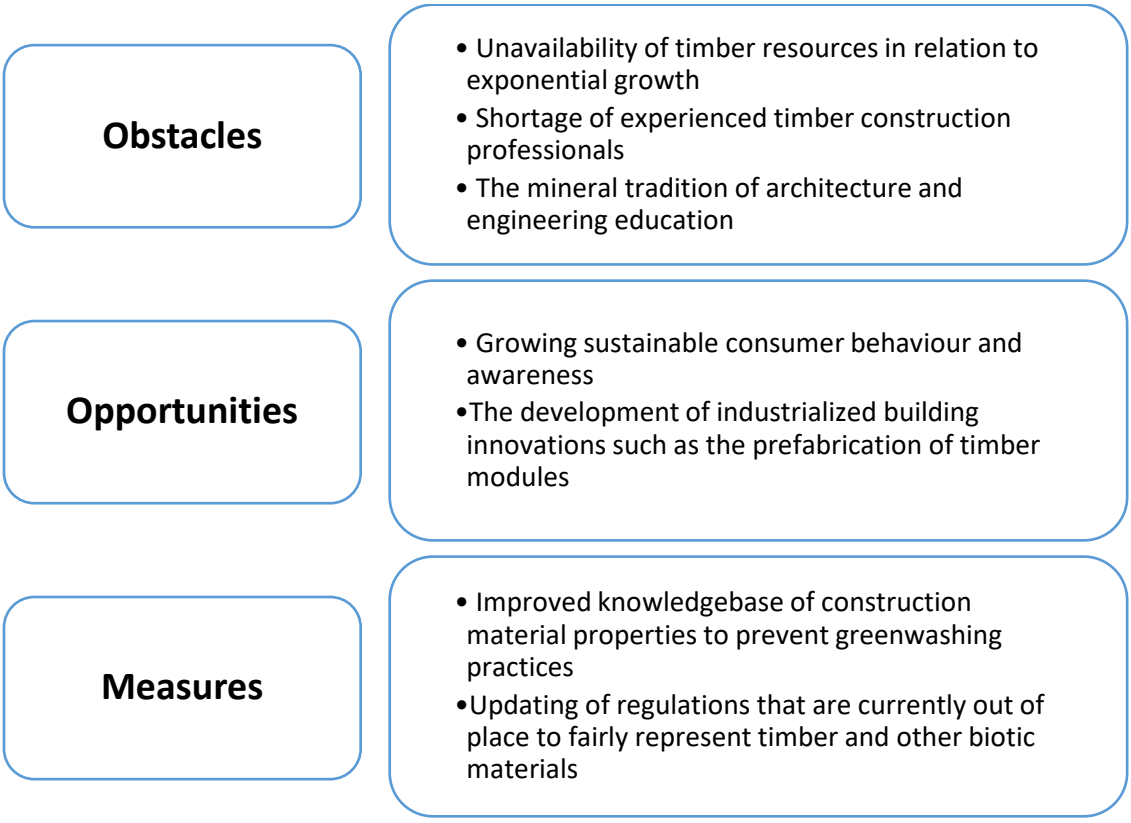

Figure 14: Overview of Findings in the Paris Scenario

3.5 Robust measures

The experts have provided their personal perspectives and explorations of the different scenarios. In this they have described their expectations in regard of opportunities, obstacles and the appropriate measures within these specific circumstances. The description of the results in the previous sections allows the formulation of the most significant measures. These measures are deemed necessary to be able to benefit the scenario specific opportunities and overcome those obstacles that have been identified by the experts. They are therefore emphasised as vital steps towards the establishment of the desired future and can be recognized in all three of the individual scenarios allowing them to be defined as robust.

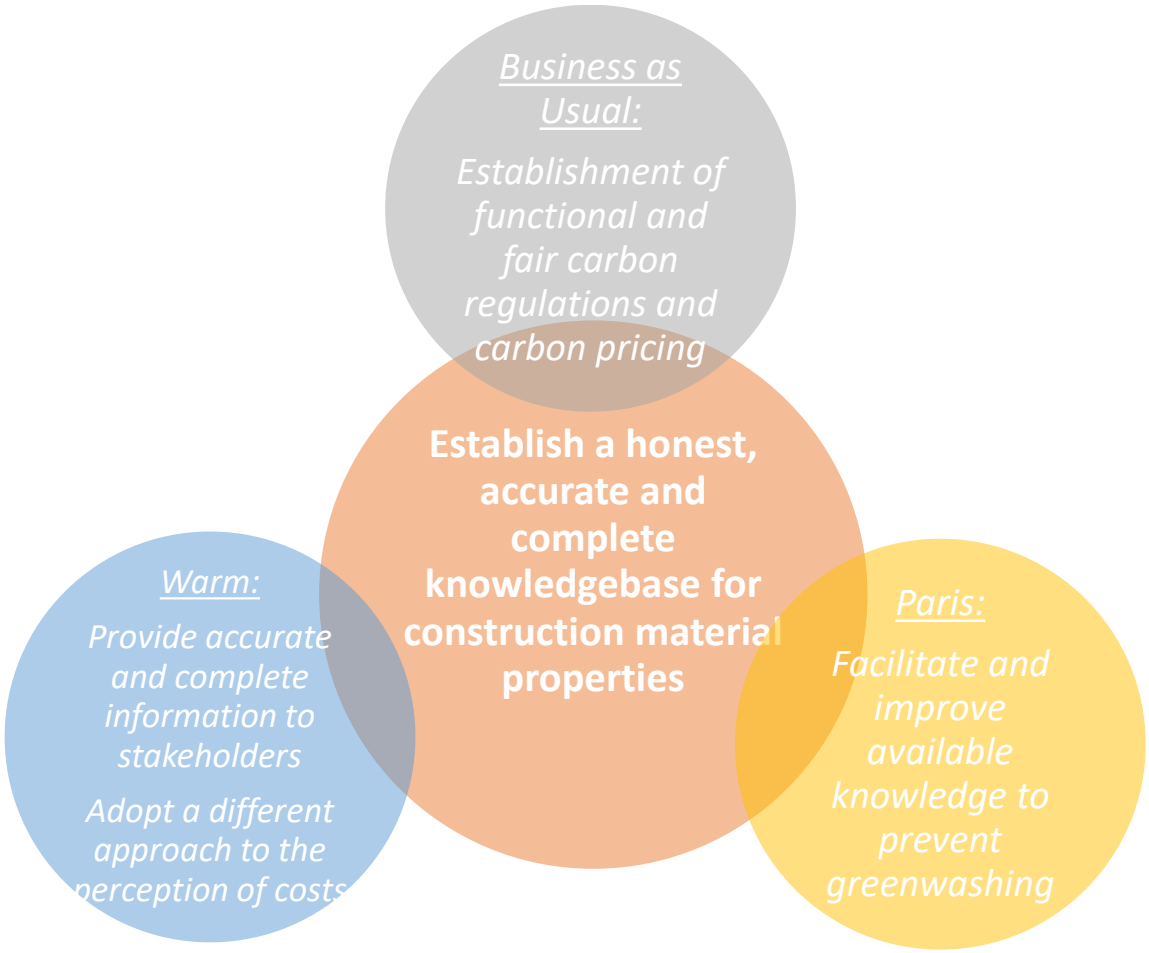

Figure 15: Robustness Check based on most dominantly mentioned Measures

Based on the analysis of 15 expert interviews, in which individual perspectives are given on possible future scenarios and the potential opportunities, obstacles and appropriate measures associated, the robust measures could be identified. Underlining the most dominantly mentioned measures for each scenario resulted in a clear concurrence between the scenarios. These dominant measures have been united and summed up as *the establishment of a honest, accurate and complete knowledgebase regarding construction materials and their carbon storing and emitting properties*.

This robust measure has been defined based on the identification of the most important measures in the Business-as-Usual scenario; *Establishment of functional and fair carbon regulations and carbon pricing,* the Warm scenario; *Provide accurate and complete information to actors and stakeholders taking part in this transition & The adoption of a different approach to the perception of cost of construction,* and the Paris scenario; *facilitation and improvement of available knowledge in regard of stored and emitted carbon to prevent greenwashing.* These four independent measures are compressed in the formulation of one single robust measure. It is therefore that this robust measure comprises of different important aspects which can be translated into robust sub-measures and conditions.

First of all, the establishment of a honest, accurate and complete knowledgebase is vital for the functionality and efficiency of carbon-based regulations and carbon pricing policies. As has been repeatedly emphasised, the current material database, accounting for carbon properties in the production and use of materials, is incomplete and lacks accurate information about the different and

especially new and innovative products such as timber and other biobased materials. This effectively undermines the purpose of those regulations that rely on this information for their calculations and assessments, and consequently the setting of proper environmental standards. When carbon pricing schemes such as the current ETS are more widely and strictly deployed it is vital that information about materials are accurately represented and up to date in regulations and in environmental databases for it to serve its purpose effectively. It has been stressed that both the carbon regulations and pricing schemes could have a substantial impact on the development of mass timber construction, yet it must be noted that this is entirely dependent on the establishment of a honest, accurate and complete knowledgebase.

Correspondingly, the establishment of knowledge-based, accurate and functional regulations is key in attracting investors and consequently financial means for the execution of mass timber construction projects. Experts explain that the environmental criteria from the regulations is also used as a primary indicator for the evaluation of environmental values in a building. Implicating that the inaccurate representation of environmental criteria in these regulations are translated in the valuation of the real estate. Large investors, such as pension funds, who hold real estate as part of an investment portfolio are because of this inaccuracy inclined to invest in less sustainable buildings. As these investors and financiers play a vital role in the execution of construction projects their choices are often decisive.

The second robust sub-measure is the establishment of a more complete perspective on costs of construction. Experts explain that it is common for construction projects to be financially assed based on the initial construction costs. This initial assessment only represents a section of the costs and often does not include construction time, transportation costs, environmental costs, the stored value of materials and re-utilization values. Based on this conventional assessment of initial costs timber and other biobased building materials are often quickly surpassed because of their relative high purchasing price. The development of different tools that could asses the total cost of a construction project has been recognized as a potentially impactful measure because it enlightens different qualities of these new materials that otherwise remain overshadowed. Again, the functionality and efficiency of such tools depends on the establishment of an accurate and complete knowledgebase, allowing a holistic perspective on the costs of mass timber construction.

The third identified robust sub-measure is the providing of accurate and complete information to actors who fulfil a central role in the material transition of the construction sector. One of the most often encountered expert statements is that too often actors that make decision do not have the appropriate information available. These actors are identified as policy makers, deputies, financiers, residents, and construction companies among others. In line with the above mentioned sub-measures the establishment of an accurate and complete knowledgebase sheds light on different aspects that could otherwise be overlooked. It is emphasised that the people who are situated on positions of influence in the sustainable innovation and development of the construction sector therefore have all possible information available and thus are not at risk of making decisions based on incomplete or clouded judgement by conservative lobbyists.

The fourth and final sub-measure is the establishment of a honest, accurate and complete knowledgebase necessary to prevent the risk of greenwashing and false advertisement. Experts have expressed that for as long as regulations and environmental databases are not accurate there is a risk that companies might exploit the flaws in these regulations and pretend to conform sustainable practice. It is not uncommon for companies to lift on the popular narrative without actually representing it, which is also known as greenwashing, and effectively deceive consumers into the buying of their product. Experts have stressed that this can be prevented when accurate and complete information is available to consumers and when regulations are accurate and up-to-date.

Chapter 4 - Discussion & Conclusion

4.1 Reiteration of the Problem Statement

Forest ecosystems and their capacity to sequester and store atmospheric carbon dioxide through the process of photosynthesis play a vita role in climate change mitigation. More recently, forests are being highlighted in the development of the bioeconomy, an economy that runs on biologically produced resources, more commonly referred to as biobased resources. Engineered biobased materials are recognized as potential substitutes for abiotic fossil-based materials and could consequently significantly reduce greenhouse gas emissions. This is especially the case for industries that are demand large amounts of primary mineral resources such as the construction sector.

Leskinen et al (2018) calculated the substituting potential of wood-based materials for the construction sector in their research for the European Forest Institute. They calculated an average substituting factor of 1,2 kg C reduced / kg C stored (Leskinen et al., 2018). This means that for every kilogram of carbon stored in wood products substituting the conventional material, the emission is reduced by 1,2 kilogram carbon. Leskinen et al. (2018) calculated that substituting these fossil-based construction materials could account for 89 million tons of CO_2 globally in 2030. This substitution potential underlines the significant impact the application of wood-based building materials, more commonly known as timber, could have on the construction sectors environmental impact. Especially in regard of the enormous amounts of materials used in construction that could be substituted for biobased alternatives.

However, the large scall adoption of a new primary building material in a sector known to be traditional is expected to go through a series of barriers and obstacles. Yet, the sense of urgency for the construction sector to become more sustainable could be large enough to force conservative minds into new and innovative pathways encouraged by the prospect of new possibilities. A particularly large role is dedicated to the government who have the responsibility to provide functional law and regulations and facilitate a level playing field for new innovations (Brink et al., 2021).

This research has specifically focussed on the identification of policy measures that are expected to significantly contribute to the large scale adoption of mass timber construction in residential and non-residential buildings in the Netherlands in 2050. This focus is central to the larger material transition needed for the establishment of a circular economy in the Netherlands in 2050. In this research obstacles, opportunities and measures have been identified through expert explorations of different possible future scenarios. These explorations resulted in a collection of robust measures recognized as vital in *substituting as much fossil-based construction materials with timber as possible within technological, sustainable and rational boundaries*, corresponding to their desired future for 2030 and 2050. Through the formulation of robust policy measures necessary to attain the expert identified desired future for mass timber construction in 2050, the research has fulfilled its objective to produce a policy recommendation.

Mass timber construction has been documented increasingly in The Netherlands as it has been gaining attention in the media because of new statements of dedication made by major construction businesses (BAM, Heijmans, Dura Vermeer) as well as position papers published by banks (ASN Bank, ABN Amro) and investors (Syntrus Achmea). This resulted in different explorations of the development of new innovations of engineered wood products mostly documented in grey-literature. This study makes a valuable contribution to the academic databased through the application of three explorative future scenario's and backcasting exercises in semi-structured expert interviews on mass timber construction in the Netherlands in 2050. Despite the fact that there has been other scenario approaches published recently, the specific methodological approach of this study has not been

documented before in academic literature and its results as well as methodological approach contribute valuable new insights.

4.2 Conclusions

4.2.1 Desired future

The primary phase of the data analysis was the identification of the expert's desired future for 2030 and 2050. As has been mentioned before, this was challenging because all experts were invited to present their personal perspective and vision in relation to the future of timber construction. This resulted in a large variety of qualitatively and quantitatively express perspectives which were not easily united under a single desired future. Notwithstanding this variance in perspectives, some specific ideas about what timber construction should and especially should not become were dominantly present. As has been shown in the results, timber construction is regarded as a means to significantly contribute to a more sustainable construction sector and a steep reduction in the use of primary abiotic resources. This motivation was also identified in the expert's desired futures, underlining especially that timber construction should be used as much as possible without compromising the sustainability of the product, which accounts for the use of resources but also the safety and durability of the construction itself. This line of thought therefore became a central aspect of the expert's desired future, substantiated by the quantitatively expressed minimums and desires for 2030 and 2050. This resulted in the articulation of the desired future: *Substituting as much abiotic construction materials with timber as possible within technological, sustainable and rational boundaries. Aiming for 20% timber in total material volume in 2030, and a minimum of 50% and up to 100% timber in 2050 in residential and non-residential buildings within the specified conditions.* This desired future became the point on the horizon based on all experts input and fulfilled a central role in the backcasting and respectively the identification of obstacles, opportunities and measures.

4.2.2 Explorative Scenario analysis

One of most noticeable things during the analysis of the scenario specific results was that the Business-as-Usual scenario generated significantly more response and elaborated answers to the interview questions compared to the explorative scenarios. This can be clearly recognized in the *Total Codes* graph below, indicating the total amount of Codes ascribed to different quotations per research concept and scenario.

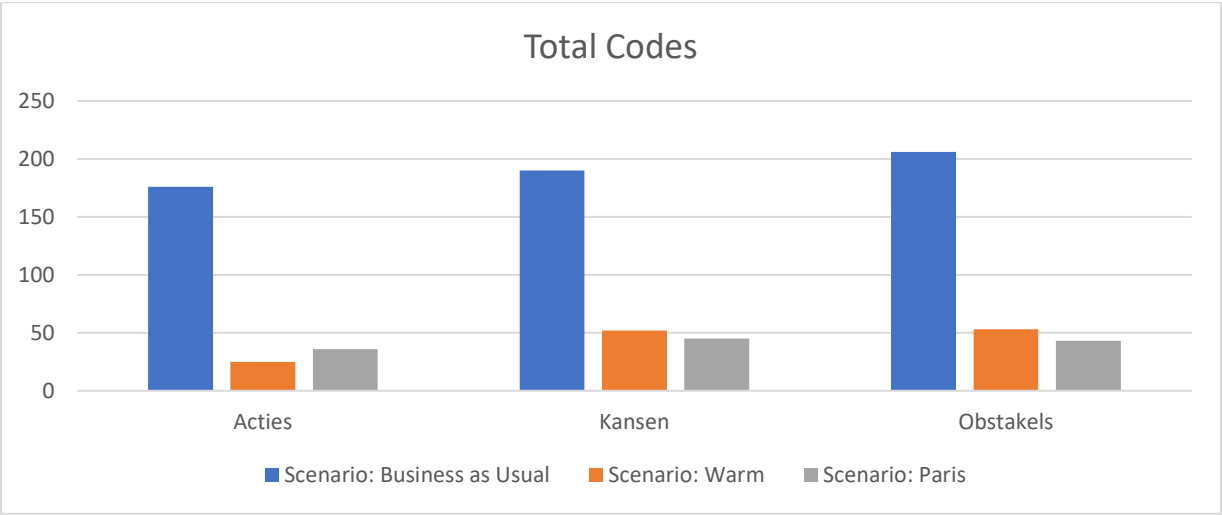

Figure 16: Total amount of applied codes per Scenario

The most logical explanation for this difference in quotations is that the business as usual scenario remains close to the contemporary situation and therefore the experts were able to reflect on what they know about the current trends. It is assumed that experts could elaborate more widely on this scenario and identify the research concepts clearly because it is less difficult imaging a future scenario that represents current trends and developments compare to unknown scenarios.

More detailed insights in the distribution of codes per category and scenario can be found in the *Code Categories* graphs that are presented underneath this paragraph. These graphs clearly represent the above identified trend in relation to the distribution of codes and show how the business as usual scenario produced the most extensive response. Furthermore, from these graphs it can be noticed what code categories are more or less related to the Warm or Paris scenario. For instance, the codes related to Policy and Government are much less associated as an obstacle in the Paris scenario and recognized more in relation to codes in this category associated to an opportunity. The scenario Warm shows the exact opposite, with a larger association to obstacles and less so to opportunities for the category of Policy and Government. This shows how the different scenarios change the expert perspectives. In the results section this and other findings will be addressed extensively and its insights supported by expert citations from the interviews.

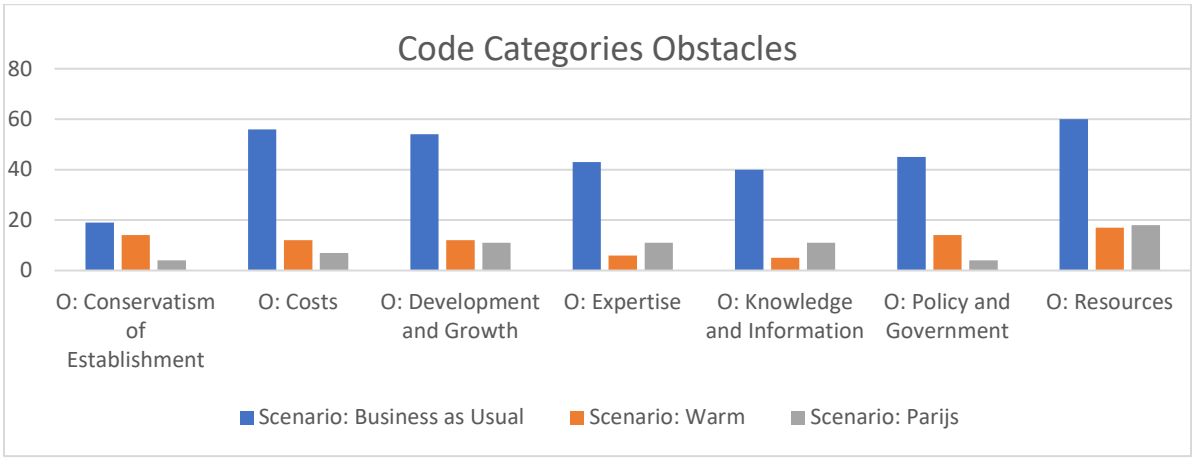

Figure 17: Total amount of applied Obstacle codes per code category per Scenario

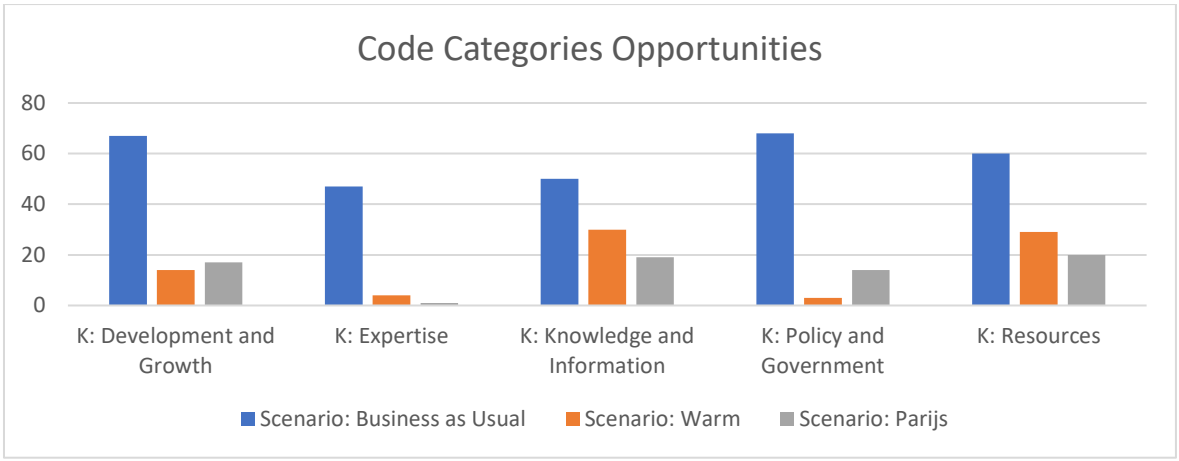

Figure 18: Total amount of applied Opportunity codes per code category per Scenario

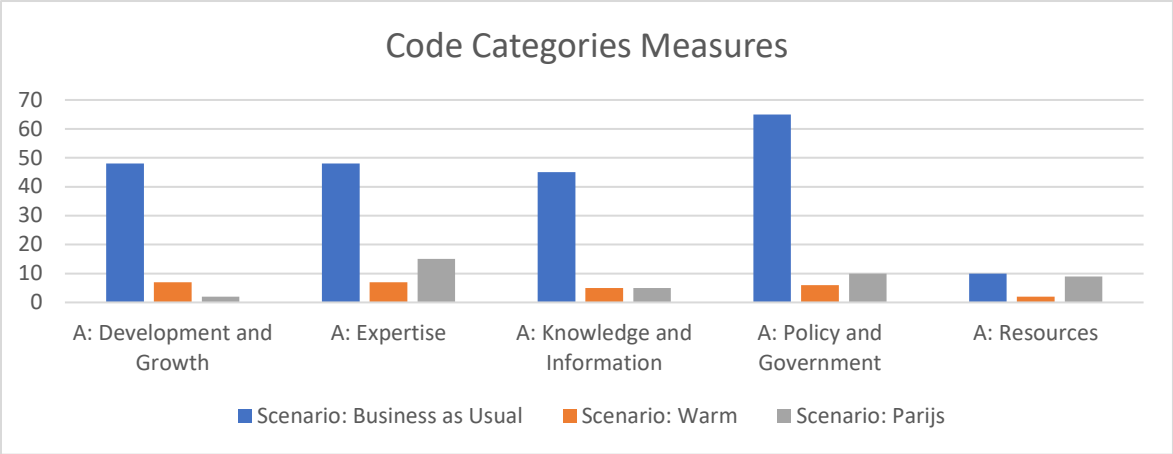

Figure 19: Total amount of applied Measure codes per code category per Scenario

The data analysing software ATLAS.ti 22 has proven to be a very efficient analysing tool allowing the researcher to create a clear overview of the complete dataset. Based on the extensive use of coding and categorising the different relations became clear and the divisions could be made between scenarios and the most mentioned obstacles, opportunities and measured. This could be done effectively with the analysing tools integrated in the software, facilitating cross references and co-occurrence tables between all the interviews. These tools allowed the selection of, for instance, the different scenarios and a specific code or category, consequently presenting all the quotations in the dataset that were coded with the scenarios and the specified code or category. This tool has also been used to provide the researcher with the information presented in the graphs included in this section and the Appendix.

4.2.3 Robust measures

Based on the analysis of the collected data several dominant themes became evident in relation to the research concepts. The most dominant of these were identified in one robust measure, encapsulating a significant fraction of the most mentioned expert perspectives and summarising the associated measures. This robust measure; *the establishment of a honest, accurate and complete knowledgebase regarding construction materials and their carbon storing and emitting properties*, is therefore recognized as the most dominant and most important result. As has been described in the corresponding section, this measure contains different sub-measures that have been identified by the experts in the scenarios. Together these measures express the facilitative responsibilities of the government and the different areas of action for the improvement of policy instruments and regulations that are desired in the development of mass timber construction towards 2050.

4.3 Literature Reflection

4.3.1 Academic Literature Reflection

Most of the recently published articles addressing developments in mass timber construction, or biobased construction materials in general, in the Netherlands categorise as grey literature. Academic literature addressing the development of mass timber construction in the Netherlands is rather sparse. In Germany and Scandinavian countries, on the contrary, there have been more academic publications in relation to the development of mass timber construction. This can be explained by the historic tradition of timber construction in these countries and correspondingly their much larger timber industries. A selection of these academic publications will be reflected upon in the following section, to counterbalance the unavailability of studies focussed on the Netherlands.

One of the countries that has a large tradition in timber construction is Germany. The German government has been actively pursuing their bioeconomy and dedicate a large share of it to its forestry sector. Numerous academics have dedicated studies to the development and potential of the German bioeconomy and the role forests and timber will fulfil in its realisation (Hagemann et al., 2016; Szichta, Risse, Weber-Blaschke, & Richter, 2022). In their scenario analysis study, Hagemann et al. (2016), underline that for a timber-based economy to succeed the advantages in sustainability are transparent and have to be clearly discussed. They found this as an important aspect of the establishment of willingness to pay and willingness to invest of consumers and producers, respectively (Hagemann et al., 2016). Also, they identify that there is a need to guarantee sustainable practices in relation to the use of biobased materials to prevent exploitative and linear lines of production (Hagemann et al., 2016).

Even though Hagemann et al. (2016) do not specify for mass timber construction in their scenario analysis, they identify important pathways and constraints in line of a potential growth of a wood-based economy. In this study numerous obstacles have been associated with the exponential growth of mass timber construction and the consequences this could have for timber resources and sustainable management of forests. One of the measures identified in this research is the guaranteeing of sustainable practices through forest certifications by the government. Also, experts have identified specific conditions in relation to their desired future aimed partly at the prevention of exploitative and linear resource extractions. In their article, Hagemann et al. (2016) again underline the importance of those demarcations to resource extraction and sustainable management of those natural resources.

Another European country with a large timber tradition is Finland. The Finnish government has been actively promoting the use of timber in construction, however their aims occasionally turned out to ambitious (Hurmekoski, Pykäläinen, & Hetemäki, 2018; Riala & Ilola, 2014). Different studies in Finland have used scenario approaches to analyse the development and potential of mass timber construction (Hurmekoski et al., 2018; Riala & Ilola, 2014; Soimakallio, Saikku, Valsta, & Pingoud, 2016). In their study, Hurmekoski et al. (2018) applied a similar research methodology as has been done in this study. Making use of a explorative Delphi backcasting approach to define long-term targets. They identified two pathways that could meet the ambitious targets of the Finnish government. The first focussed on the credibility of the construction professionals and the need to increase competition between them, aiming to *"creating more options, reducing costs and improve quality"* (Hurmekoski et al., 2018). The second pathway emphasises more direct supporting policy measures. One of the underlined options here is the "*Polluter Pays principle"*, this entails the integration of external environmental and social costs into the costs, addressing environmental impact more directly (Hurmekoski et al., 2018).

The two main pathways identified in their study show some clear resemblance with the findings in this study. First of all, this study identified the availability of professionals as an issue, but also the risk that the insufficient amount of construction professionals could result in unqualified workers providing construction of poor quality. As Finland has more timber construction professionals this measure would be more simply applied than it would be in the Netherlands, however, competition in the Netherlands would likely have a positive effect on the quality of construction in similar manners.

The second pathway by Hurmekoski et al. (2018) emphasised the integration of environmental performance in the costs of construction. This aligns with the findings in this study; underlining the environmental performance of materials and integrating this in regulations, but also addressing these environmental characteristics in a different perception of price and consequently costs. External costs are often emphasised as an important neglect in how costs of construction are recognized. Integrated approaches to the costs of construction could also address circumstances around the construction site

and the added value of healthy living conditions, something that has also been touched upon by experts in this research.

4.3.2 Grey Literature Reflection

In the Netherlands there has been a growing interest in possibilities and innovations that could bring down material and resource consumption. Addressing the linear trends in primary resource use and its associated greenhouse gas emissions are a central aspect in the Dutch governments environmental policy strategy. This is illustrated in their aim to achieve a completely circular economy in 2050 and reduce primary resource use with 50% in 2030 (Rijksoverheid Nederland, 2019). The PBL has been monitoring the progress of the establishment of the circular economy and present these in periodical reports. One of the more recently published reports, the ICER 2021 (*Integral Circular Economy Rapport),* provides some concrete policy recommendations for the Dutch government in relation to the progress (Brink et al., 2021).

These recommendations are interesting for this research as they address resource use as one of the central themes. They stress the need for more demanding regulations, including the incorporation of environmental damage in material pricing and the establishment of a level playing field for circular initiatives among others (Brink et al., 2021). The PBL identifies necessary measures that correspond to the measures that have been articulated by experts in this study. Especially the emphasis on more stringent use of regulations and carbon pricing mechanisms to incorporate environmental impacts clearly aligns with the findings.

In addition to the monitoring of the circular economy by the PBL, others have focussed more on how the circular economy could present an opportunity for renewable and biobased materials. One of these is the *Timber construction Whitepaper: Building a Timber Future*, in which ABN-AMRO in corporation with Invest-NL and Circle Economy explore different future scenarios for timber construction (Bronsvoort, Veldboer, te Slaa, & Kaptein, 2020). In their whitepaper they lay-out four different scenarios and emphasise one specifically. This scenario is called *The Wooden Revolution*, a positive scenario in which policy and regulation boost the development of timber and other biobased construction materials, resulting in the application of 80% biobased materials in residential houses constructed (Bronsvoort et al., 2020).

To attain this scenario they specify necessary actions and conditions that have to be in place. They especially emphasise the need for the upscaling of the production capacity and the development of the value chain to be able to answer the substantial increase in demand (Bronsvoort et al., 2020). Additionally they focus on the establishment of a knowledge platform to support innovation, education and awareness in relation to timber and biobased construction (Bronsvoort et al., 2020).

In their paper, in particular the Wooden Revolution scenario, shows a lot of resemblance with the Paris scenario in this study. Both scenarios include a specific focus on environmental policy and regulations that promote the use of carbon intensive materials. Strikingly, their findings compared to the findings from the Paris scenario correspond in the amount of emphasis on the potential obstacles associated with an exponential incline in timber construction demand. The development of the value chain has, however, not been directly articulated as a significant measure for the Paris scenario, contrasting the whitepaper by Bronsvoort et al. (2020).

Other impact studies, position papers and strategical explorations have been published in 2021 by TNO, Syntrus Achmea Real Estate & Finance and ASN Bank & Climate Cleanup respectively (ASN Bank & Climate Cleanup, 2021; Keijzer, Klerks, van Leeuwen, Nijman, & Fraanje, 2020; Syntrus Achmea Real Estate & Finance, 2021). Their studies provide interesting insights from different perspectives, looking

especially into the carbon storing properties of biobased buildings and how this will be financially interesting. Their conclusions present interesting comparisons with this study and emphasise different findings that have been done in this research more extensively.

In their study the TNO (2021) concludes that the calculations of the MKI (Milieu Kosten Indicator) and the MPG have not adequately integrated the stored carbon in biobased materials. This has also been repeatedly emphasised by the experts in this study as a major obstacle. The TNO (2021) study emphasised that integrating these properties into the calculations would substantially improve the environmental performance of these products. As has been underlined in this study, the accurate representation of the environmental performance of these materials would effectively address this initial obstacle.

Syntrus Achmea Real Estate & Finance (2021) also underline the need for a level playing field in which all materials are accurately integrated in the regulations. Additionally they emphasise the need for more experience and knowledge in the field of timber construction. This is necessary to guarantee the quality and durability of construction, this is especially important for investors and developers. This also aligns with the findings in this study, emphasising the need for more and better equipped timber construction professionals.

Finally, the ASN Bank in cooperation with the Climate Cleanup (2020) especially underline stored carbon in construction in their paper. They recommend the adoption of different perspectives to the costs and value of buildings in their *Metric for Construction Stored Carbon* (ASN Bank & Climate Cleanup, 2021). This metric aims at financially recognizing the material and carbon value of buildings. A different and more integrated approach to the perception of costs is also part of the findings in this research, addressing especially the taking into account external costs and the benefits of working with engineered wood products over abiotic materials.

4.4 Complementary findings

4.4.1 Obstacles and opportunities

Despite the largely encapsulating robust measure there remain some identified opportunities and obstacles that have not been connected to appropriate measures by the respondents. In the following section these opportunities and obstacles will be given some more attention, making use of the complete data set to allow the researcher to make a personal assessment of potentially fitting measures and where necessary supported by related academic and grey literature.

This most notable obstacle that is not included in the identified robust measure, is the *unavailability of mass timber construction resources in relation to an anticipated exponential growth of the demand in timber construction*. In this, mass timber construction resources is used as an umbrella term for human and material resources in relation to timber construction. Respectively, mass timber construction resources include the availability of productive forest and hence wood as a basic resource for timber, the timber processing and engineered wood producing facilities, and the availability of timber construction professionals. Essentially, timber construction resources in this instance represents a large share of - and could therefore be understood as - the mass timber value chain.

Experts explain that a rapid increase in the demand of mass timber construction projects could result in highly pressurised areas on the value chain. The most mentioned being *certification and sustainable forest management, processing capacities of sawmills and engineered wood factories, and availability of construction workers with adequate knowledge and skills on mass timber products*. These are all recognized as equally important in the deliverability of mass timber constructions and experts express their worries in regard of the preparedness of the value chain for a sudden incline in demand. This is

especially problematic because when one of these value chain processes lacks the capacity to deliver it directly influences the whole chain and this could result in steep price increases.

This shared worry is also directed at some inherent issues concerning the value chain. First and most fundamentally is the biotic character of timber and therefore its natural production. This means, the production rate of timber is inherently limited by the growing capacity of trees which again depends on the specific surroundings this tree is positioned in such as the availability of light, water and soil. Therefore the supply of timber is and will remain to be bound by seasonal and natural cycles and conditions. Within sustainable management practices it is only possible to harvest as much as the annual forest regrowth, consequently keeping the standing forest biomass in balance. Forest management and reforestation could result in increased forest production rates and effectively allow more wood to be harvested within sustainable practices, yet more extreme climatic events such as droughts or storms could present significant future challenges (Verkerk et al., 2020). It is therefore repeatedly emphasised that forest certifications will have an important role in safeguarding the health and quality of forests in the future. Governments are also recognized for their actions and responsibility towards forest policy, reforestation and protection of vulnerable forest ecosystems, especially in consideration of future impacts of climate change (Verkerk et al., 2020).

Another key aspect in the value chain is the timber processing and producing facilities. They have also been repeatedly mentioned as a vital potential bottleneck. This emphasis could be explained by more recent developments experienced on the European timber market, which has seen exponential price increases due to a significant supply deficiency. This shortage can be connected to different global events resulting in high demands for European timber which had not been anticipated on. Experts have emphasised that to prevent the occurrence of such steep price fluctuations the processing facilities, particularly the sawmills, should be better equipped to handle much higher capacities in the future.

The third aspect in the value chain of mass timber construction brings us to the execution of construction itself. It has been identified by the experts that a tradition of concrete and steel has been dominant in the construction sector as well as its educational programmes for close to a century. Experts explain that the lack of an educational chair representing timber construction in engineering educational programmes has resulted in a scarcity of specialised professionals in the Netherlands for a long time and that a lot of knowledgeable people are currently sought after abroad. In anticipation of the exponential growth in the demand of mass timber construction the lack of adequate knowledge is therefore seen as another possible bottleneck in the value chain.

4.4.2 Complementary Measures

These three potential bottlenecks in the development of mass timber construction towards 2050 have been stressed particularly in a situation where fast and exponential growth surpasses the timber construction value chain's capacity. The latter is expected in both the Business-as-Usual scenario and the Paris scenario. In the Warm scenario the lack of timber resources is also underlined, yet, in relation to environmental degradation as a result of climate change rather than exponential growth. It is therefore necessary to identify measures that would contribute to the establishment of a stable and continuous European timber market and value chain.

The first measure, ascribed to the risk of overexploitation and unsustainable forest management, can be regarded as relatively straightforward. In the current forest management practices there exist two large certifying bodies who guarantee and safeguard global sustainable forest management, these are FSC and PEFC. Experts from both of these organisations explained that when timber products originate from certified forests it can be guaranteed that these natural resources are managed sustainably and therefore can remain their productivity for a very long time. When certified forest products are in

demand it promotes certification and effectively allows FSC and PEFC to expand the total amount of protected and sustainably managed forests worldwide. This could result in the establishment of heathy, protected and productive forests globally. Therefore the national government should exclusively facilitate the use and application of certified timber and discourage the use of noncertified timber products.

A further opportunity that has been repeatedly mentioned by the experts is the assurance of future mass timber construction projects. Constructors, processing and engineering facilities need to be confident about their future demand before they start investing in new systems. Traditional construction companies often have capital invested in conventional mineral building systems and facilities. They would need to reinvest their capital because timber construction demands the adoption of new building systems and different skillsets, therefore also the re-educating of their personnel. Sawmills and engineered wood facilities also need assurance of future demand for the development and expansion of their processing capacity. A sense of security is thus pivotal and could be accomplished through statements of dedication, such as the Green Deal Timber Construction of the Metropolitan Region of Amsterdam. National governments are emphasised as well, they could follow the example the French government who set a minimum of 50% timber in all new government buildings. Also, municipalities, housing associations and project developers and investors could dedicate a percentage of their future projects to timber construction and by doing so contribute to a stable and continuous market. The constructors and developers with this sense of security are able to make agreements with sawmills and engineered wood facilities for their supply and consequently allow them to invest in their processing capacity. Additionally, national policies aimed at subsidising investment in new and innovative building systems could be designed to overcome this initial investment barrier.

Finally, another associated measure that has been mentioned by the experts is the investment and establishment of an university chair and applied science programmes that specialise in timber construction engineering and research. Primarily such a chair should be installed to oversee the progression of the educational programmes, but also the production of knowledge in relation to innovations in timber construction. This is deemed very important in preventing poorly designed or executed construction projects that could negatively impact the reputation of timber construction. This chair could be mobilised to safeguard the construction of timber buildings and guarantee its quality and safety, while simultaneously encouraging the exploration of such innovations and education new timber construction professionals.

The three measures above have been connected to the expert's worries concerning the availability of mass timber construction resources. These measures have been based on the total dataset of expert interviews and have been connected to these measures based on the researchers personal assessment. Additional obstacles and opportunities remain, however, they are beyond the scope of this specific research. The additional findings described above have been used for the formulation of the recommendations for further research in the following section.

One of the opportunities that has been identified but not further explored in this research is the potential of industrialised building systems. Different experts explain that a whole new branch of construction has to potential to revolutionise the contemporary building system. Working with prefabricated lightweight modules, that can be produced offsite and at a spectacular rate, are recognized as potential gamechangers because of the reduce transportation costs, onsite (noise) pollution, construction time and foundation necessities, among others. An exploration of this potentially revolutionary new construction system is recommended and can be recognized as a valuable addition to this specific study.

Additionally, the potential and impact of other biobased building materials could also be explored. Particularly looking at fast growing natural products and their substituting potential in relation to conventional building materials and applications such as isolation. These innovations are also very interesting in relation to the current nitrogen depositions and correspondingly a possible agricultural transition. Presenting very interesting and relevant perspectives on contemporary issues as well as the sustainable transitions of the construction sector.

4.5 Complementary Robust Measure

Based on the obstacles and opportunities identified in the above section an additional robust measure can be formulated. This robust measure has not been explicitly formulated by the experts, yet it is considered a valuable addition because it addresses an obstacle that has been frequently identified during the expert interviews. The researcher has therefore formulated this additional robust measure based on the complete dataset resulting from the expert interviews.

As has been shown, the processing capacity of the mass timber construction value chain is identified as a significant aspect in the accomplishment of the expert's desired future. This has been particularly underlined for three key areas on the value chain. These are: *sustainable forest management and certification, processing capacity of sawmills and engineered wood facilities and mass timber construction professionals.* These three areas are identified as potential bottlenecks in a scenario where, either climate change impacts or exponential growth compromises the value chains supplying capacities. The measures to overcome these bottlenecks are identified as respectively;

- Governments should guarantee sustainable forest management through certification and facilitate the adoption of certifications on the value chain
- Governments should facilitate the continuous demand for timber construction projects by dedicating a minimum amount of timber to governmental buildings
- Engineering chairs and research specialised in timber and biobased construction must be established on university and applied sciences programmes

Based on these measures, corresponding to obstacles and opportunities identified in all three of the scenarios, another robust measure could be identified as: *The establishment of a stable mass timber construction value chain with a continuous demand and sustainable supply of human and natural resources.*

This additional robust measure is backed by findings from similar researches that have been presented in the Literature discussion section as well as other relevant policy and academic publications.

The research by Bronsvoort et al. (2020): *Building a timber future*, is one of the discussed publications. In their publication Bronsvoort et al. (2020) extensively describe one of their scenarios in which timber construction is adopted on a large scale, because of the implementation of encouraging regulations. Corresponding to the additional robust measure, they also identify that the outcome of their scenario primarily depends on the development of the processing capacity (Bronsvoort et al., 2020). They also underline the need for assurance in future demand, development of timber processing facilities and the expansion of timber construction knowledge and professional skills, among others (Bronsvoort et al., 2020). The findings in their whitepaper therefore aligns with the formulated measures corresponding to the additional findings.

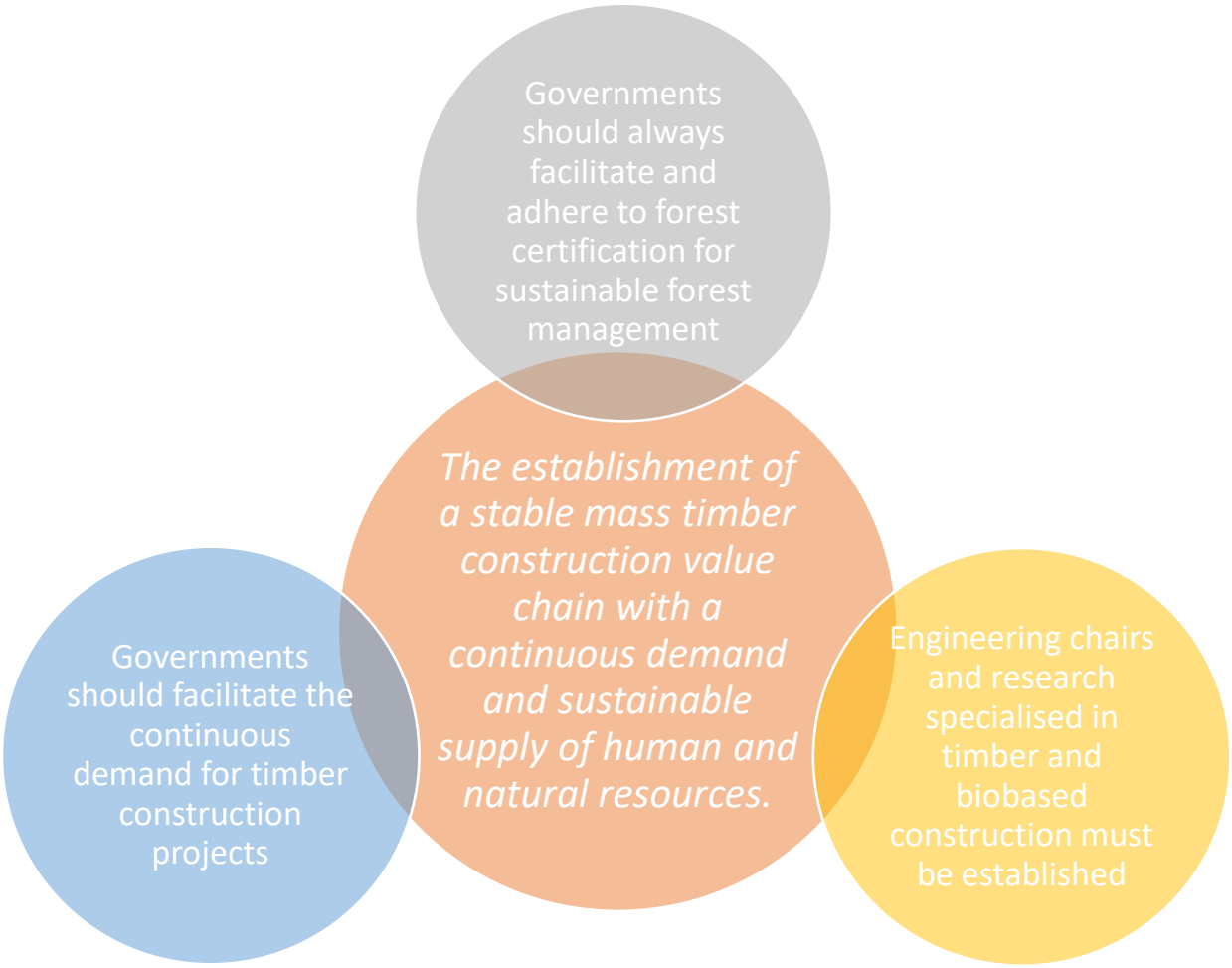

Figure 20: Robust Measure based on dominantly mentioned opportunities and obstacles (By Author, 2022)

In relation to the continuous and sustainable supply of resources, plentiful academic studies have been done emphasising sustainable forest management. Nabuurs et al. (2018) especially underlines the importance and the role of forests in the mitigation of climate change. In his article he argues that Climate Smart Forestry should be adopted as a management and policy principle to allow forest based climate change mitigation to be maximised (Nabuurs et al., 2018). His three central perspectives on this approach are the sequestration of atmospheric carbon in forests, building resilient forests and the substitution of fossil-based resources with associated high greenhouse gas emissions (Nabuurs et al., 2018). He concludes that, accounting for sequestered carbon in wood-based products needs to be acknowledged in order to utilise the full potential for carbon mitigation. He also underlines that the active management of forests in relation to climate change mitigation and the use of wood-based products could have significantly higher mitigation effects (Nabuurs et al., 2018). His research again underlines the relevance of mass timber construction in relation to sustainable development and his conclusions support the findings in this research. In particular, the emphasis on sustainable management and certification, as well as the facilitative responsibilities of the government (Nabuurs et al., 2018).

In conclusion, this study comes with several recommendations for the Dutch government and stakeholders along the mass timber value chain. These recommendations are particularly addressed to the Ministries responsible for policy making and implementation in relation to forest management

and the sustainable development of the construction sector; i.e. The Ministry of Agriculture, Nature and Food Quality and the Ministry of the Interior and Kingdom Relations. First of all this study recommends the government agencies to facilitate a level playing field for biobased materials in the construction sector. This can be done by the facilitation of accurate information regarding the materials environmental performance, especially in relation to the amount of carbon associated in production and use. This is vital for the functionality of construction regulations aiming to enhance sustainability. A recommendation with a long term perspective is the implementation of carbon pricing and a more holistic approach to costs of materials. Taking into account environmental damage and emitted carbon would substantially contribute to the acceleration of sustainable development and innovations. These measures are necessary because the construction sector is known to be conservative and it needs to be encouraged in its sustainable transition.

In addition, the government is also capable of facilitating demand of mass timber construction projects and this study recommends that governments dedicate a significant percentage of their construction projects in timber, allowing the value chain to grow and setting an example for sustainably constructed buildings.

To guarantee quality of construction University chairs should be installed. Chairs and their research groups should provide the studies necessary for timber engineering practices and technological opportunities. Also, the design of timber engineering programmes on Universities as well as Vocational Education can be assigned to these chairs, allowing students to specialise in this and other alternative construction materials.

Finally, maintaining a firm position in relation to certified wood-products and sustainable, climate smart forestry is vital in providing future generations with productive forest ecosystems. The government has a responsibility to supervise the quality and productivity of forests nationally and allow a balanced and symbiotic relation between its utilisation and biodiversity.

4.7 Methodological approach

The methodological approach in this study was initially designed as a participative backcasting workshop with experts. In this specific approach experts with different positions along the value chain of mass timber construction were invited to participate in the on campus activity. During this half day workshop the experts would collectively explore the different scenario's and establish a desired future outcome for 2050. The organisation of such an event and its possible barriers had been assessed as challenging, yet considered worthwhile. Unfortunately organising this event during the COVID19-pandemic, in a period where the specific topic and its experts were being exhausted in the media, resulted in more issues than had been anticipated. Eventually there were not enough experts available and willing to participate and because rescheduling would cause a significant delay the decision was made to cancel the workshop and redesign the data-collection method.

To allow a swift transition in the data-collection the decision was made to continue with the scenario analysis and backcasting approach. Instead of the participative workshop that had been planned, experts were invited to participate in a semi-structured interview. During these one-hour interviews the experts were in all case presented with a Business-as-Usual scenario and either the Warm or the Paris scenario. Exploring just two out of three scenarios was necessary to restrict interviews to one hour on average and to prevent the loss of interviewees interest. However, some other difficulties were experienced with the use of this specific methodology.

One of the primary difficulties turned out to be the imaginative capacity of the experts. The ability to position oneself in an completely new and previously unknown context and in addition, explore

potential possibilities, obstacles and measures associated to that unknown sphere, presented to be a significant challenge. This was especially the case in situations where experts claimed the given scenario to be unrealistic or not in line with the experts personal expectations of the future. The mental barrier to imagine something outside of what is known or expected can be strikingly illustrated by the horseless carriage syndrome, which refers to this limitation and emphasises that the unknown if often described or explained by what is already known. Nevertheless, most experts participated open-mindedly during the interviews and allowed themselves to freely debate the scenario specific features following the questions. This resulted in very interesting and insightful outcomes as well as joyful conversations on both ends.

Another encountered difficulty in this methodology has been the high variety and diversity in experts desired futures. As this fundamentally involves a qualitative questioning experts gave their perceptions also in many different forms and varieties. This resulted in some challenges during the analysis and formulating of a common desired future and demanded a relatively more open formulation that had been anticipated.

One final downside to the semi-structured interviewing methodology compared to the participative workshop is one that can hardly be overcome, being the time consuming character of individual interviews, transcription, coding and analysis. The additional hours invested, however, are worthwhile considering the depth and extent of the interviewees insight.

The backcasting approach in semi-structured interviews did also present some noteworthy advantages to the research and particularly to the collected data. Despite the time efficiency of a participative workshop and its additional contribution in terms of a collective process, some limitation to workshop are overcome through semi-structure interviewing. First of all, in a collective process there is a possibility of dominant and less dominant participants, this could result in the overrepresentation of some of the participants and underrepresentation of others. Also, during the participative process of the workshop participants could influence each other's line of thought and perhaps prevent participants to arrive at a different point or interpretation, which than could be considered lost. It must be stressed that the backcasting approach through semi-structured interviews allowed all participants to present and develop their own personal perspective within the different scenarios and all were allowed the space and time necessary for them to explain themselves. Consequently, all experts in this study were able to equally impact the outcomes without external influence or overshadowing of their perspective. The additional time and effort therefore resulted in very detailed and comprehensive descriptions and consequently complete and insightful results.

The strategic foresight theory has proven to be very applicable and effective in this study. As has been described in the Theoretical Methodological Background section, the strategic foresight approach and especially Scenario Analysis, have become popular instruments in environmental impact research. The Backcasting method, especially applicable in complex and system wide problems with high levels of urgency, has also shown to be an effective research method in this study as it allowed the researcher to established a point on the horizon, or desired future. This methodological feature has been an essential starting point for the experts to direct their expectation when they explored the different scenarios. This also allowed the researcher to redirect the experts when they extended beyond the research relevancy, providing some structure to the interviews.

4.6 Conclusion

Governmental institutions are looking for efficient climate change mitigating solutions with increasing urgency. One of these solutions is expected to be found in the establishment of a circular and biobased economy. Substituting the most environmentally damaging materials with renewable resources is a

key aspect in this fundamental transition. Different biotic materials are being explored for their capacity to substantiate plastics, minerals, chemicals and other polluting materials with large fossil-based resource dependency. These biobased materials are becoming more and more embedded in new and sustainable practices and one could argue that a certain transitional momentum is becoming evident.

In this research the future potential and substituting possibilities of mass timber construction has been explored through the guidance of three possible scenarios for 2050. In this study 15 interviews have been conducted with experts along the value chain to identify their shared desired future and the opportunities and obstacles they expected to encounter in its accomplishment. Based on these perspectives and expectations different actions could be identified resulting in a compressed package of robust policy recommendations. The desired future identified by the experts is defined as:

- *Substituting as much abiotic construction materials with timber as possible within technological, sustainable and rational boundaries. Aiming for 20% timber in total material volume in 2030, and a minimum of 50% and up to 100% timber in 2050 in residential and non-residential buildings within the specified conditions.*

The obstacles identified for the accomplishment of this desired future within the three scenarios are numerous and to extensive to succinctly summarise. A selection of which are:

- *Availability of human and natural resources.*
- *Incomplete regulations and lacking incentives.*
- *Mineral traditions and conservative character of the sector.*

The opportunities in the accomplishment of the desired future are also manifold and therefore to extensive to completely cover in this section. A selection of the opportunities are:

- *Carbon pricing schemes and carbon storing incentives.*
- *Economically competitive timber construction qualities.*
- *Climate change awareness and sense of urgency.*
- *Industrialising of timber construction systems.*

Based on the obstacles and opportunities different important actions and measures in the accomplishment of the desired future in 2050 could be identified and collectively formulated as:

- *The establishment of a honest, accurate and complete knowledgebase regarding construction materials and their carbon storing and emitting properties.*

This incapsulates the following bundle of measures and policy recommendations expected to significantly contribute to the establishment of the desired future:

- *Establishment of functional and fair carbon regulations and carbon pricing,*
- T*he adoption of a different approach to the perception of cost of construction,*
- *Provide accurate and complete information to decision-makers in this transition,*
- *Facilitation and improvement of available knowledge in regard of stored and emitted carbon to prevent greenwashing.*

Additionally, another robust measure has been formulated based on findings that are not encapsulated by the former robust measure. These findings represented a dominant theme in the all three the scenarios are therefore recognized as an important addition. Based on the researchers assessment of the findings the following robust measure could be formulated as complementary to the one explicitly identified by the experts:

- *The establishment of a stable mass timber construction value chain with a continuous demand and sustainable supply of human and natural resources.*

This robust measure includes the following bundle of measures and policy recommendations associated to obstacles and opportunities identified by the experts in three different scenarios:

- *Governments should always facilitate and adhere to forest certification for sustainable forest management*
- *Governments should facilitate the continuous demand for timber construction projects by dedicating a minimum amount of timber to governmental buildings*
- *Engineering chairs and research specialised in timber and biobased construction must be established on university and applied sciences programmes*

These results provide valuable insights in a comprehensive and broad expert perspective on the development of mass timber construction and its significance for the establishment of a sustainable construction sector within the circular bioeconomy that is being aimed for. Policy makers are invited to take advantage of these insights as they could contribute to an informed decision making process.

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Appendix

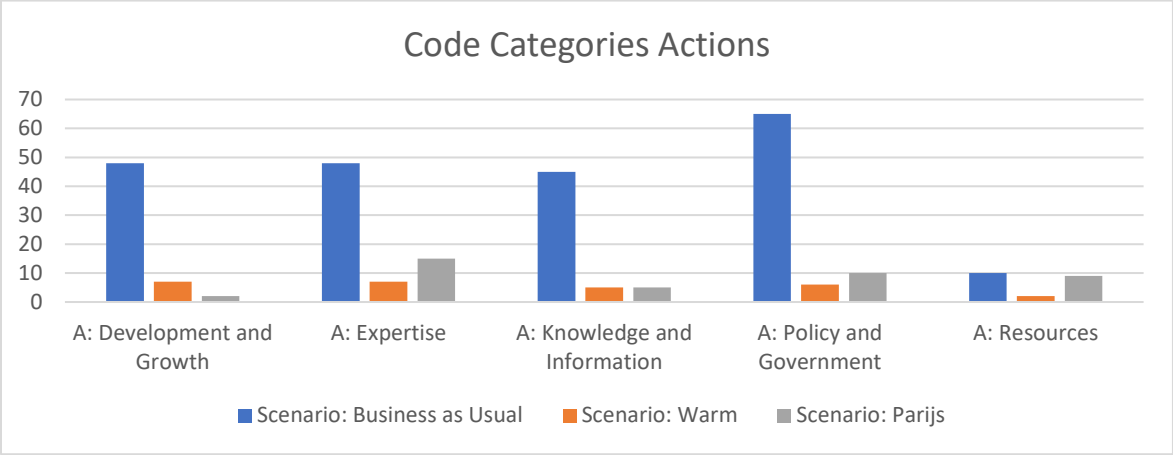
1. Codes and Coding Categories

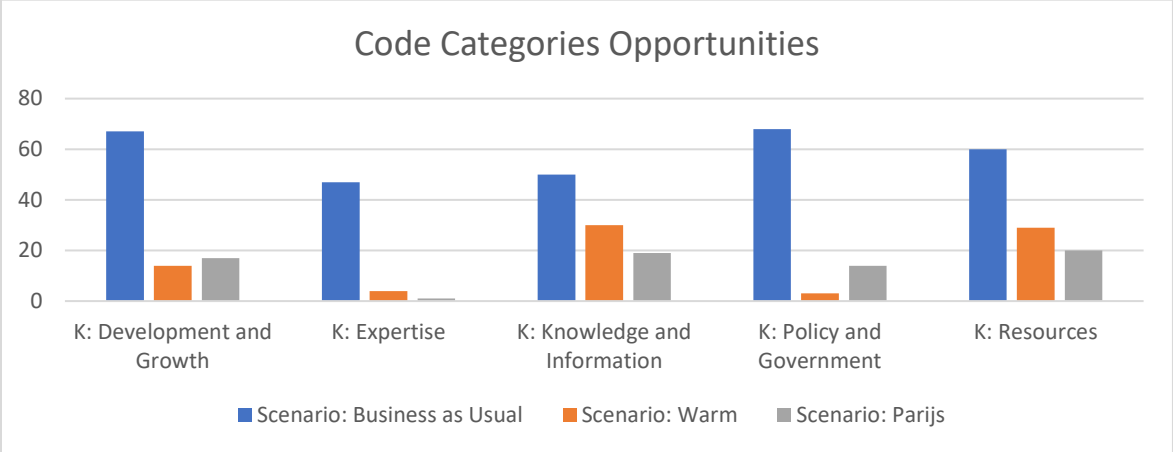
Obstacle Codes Categorised as:	
Category	*Code*
Resources	
	Obstakels: O: Grondstoffen: Hout
	Obstakels: O: Materialen: capaciteit
	Obstakels: O: Materialen: Import
	Obstakels: O: Materialen
	Obstakels: O: Grondstoffen
	Obstakels: O: Energie
	Obstakels: O: Klimaatverandering
	Obstakels: O: Boseigenaren
Costs	
	Obstakels: O: Kosten: Materiaalprijs
	Obstakels: O: Kosten
	Obstakels: O: Kosten: Onderhoud
	Obstakels: O: Verzonken Kosten
Policy and Government	
	Obstakels: O: Beleid
	Obstakels: O: Wet en Regelgeving
	Obstakels: O: Beleid: Incentieven
	Obstakels: O: CO2 Normeren
	Obstakels: O: CO2 Emissies
	Obstakels: O: Beleid: MPG
	Obstakels: O: CO2 Opslag
	Obstakels: O: CO2 Beprijzen
Expertise	
	Obstakels: O: Bouwtechnisch
	Obstakels: O: Ervaring
	Obstakels: O: Vakmensen: Kwaliteit
	Obstakels: O: Vakmensen: kwantiteit
	Obstakels: O: Vakmensen
	Obstakels: O: Bouw Projecten
	Obstakels: O: Ervaring: Voorbeelden
Knowledge and Information	
	Obstakels: O: Kennis
	Obstakels: O: Informatie: desinformatie
	Obstakels: O: Bos sentiment
	Obstakels: O: Onderwijs
	Obstakels: O: Informatie
	Obstakels: O: Wooncomfort
Conservatism of establishment	
	Obstakels: O: Lobby
	Obstakels: O: Bouw Conservatief
Development and Growth	
	Obstakels: O: Versnelling
	Obstakels: O: Innovatie drempel
	Obstakels: O: Logistiek
	Obstakels: O: Innovatie drempel: houtsoorten
	Obstakels: O: Laagwaardige toepassing
	Obstakels: O: Internationaal

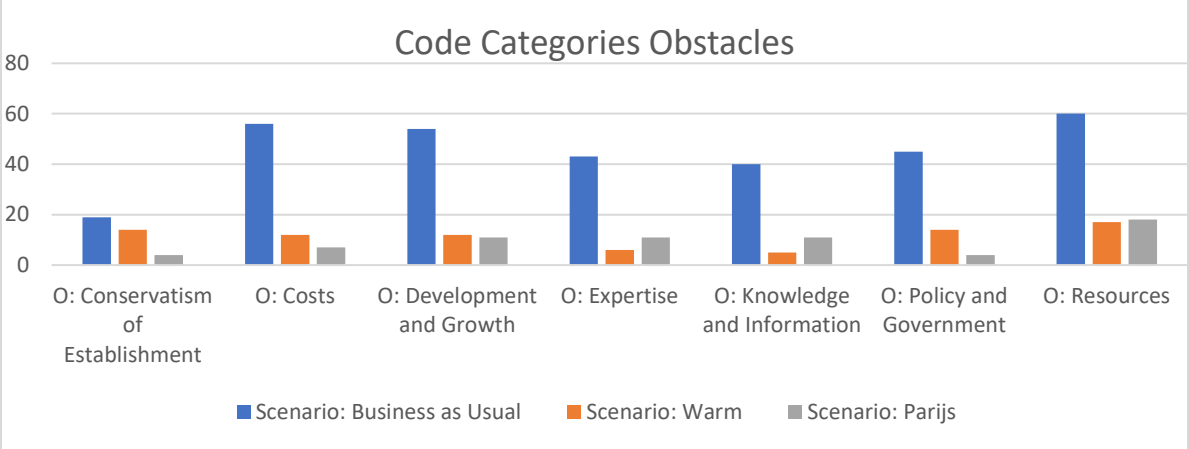
Opportunity Codes Categorised as:	
Category	*Code*
Development and Growth	
	Kansen: K: industrialisatie
	Kansen: K: Markt
	Kansen: K: Markt: Aanbod
	Kansen: K: Markt: Vraag
	Kansen: K: Investeerders: Lange Termijn
	Kansen: K: Nieuwe Innovaties
	Kansen: K: Ombouwen
	Kansen: K: Optoppen
	Kansen: K: Prefab
Expertise	
	Kansen: K: Bouwdelen
	Kansen: K: Bouwdelen: CLT
	Kansen: K: Bouwdelen: Engineerd Woods
	Kansen: K: Bouwdelen: Gevel en Wandbekleding
	Kansen: K: Bouwdelen: houtskeletbouw
	Kansen: K: Bouwdelen: Hybridebouw
	Kansen: K: Bouwdelen: Isolatiemateriaal
	Kansen: K: Bouwdelen: Massieve houtbouw
	Kansen: K: Bouwplaats
	Kansen: K: Bouwtechnisch
	Kansen: K: Onderhoud
Knowledge and Information	
	Kansen: K: Bewustwording
	Kansen: K: Faciliteren
	Kansen: K: Gezondheid
	Kansen: K: Informeren
	Kansen: K: Leefklimaat
	Kansen: K: Maatschappelijke Druk
	Kansen: K: Nationale Milieu Database
	Kansen: K: Wooncomfort
Policy and Government	
	Kansen: K: Beleid
	Kansen: K: Beleid: EPC
	Kansen: K: Beleid: MPG
	Kansen: K: Bosbeleid
	Kansen: K: CO2: Beprijzen
	Kansen: K: CO2: Emissies
	Kansen: K: CO2: Normeren
	Kansen: K: CO2: Opslag
	Kansen: K: ETS Richtlijnen
	Kansen: K: Klimaat beleid
	Kansen: K: Overheid: Opdrachtgever
	Kansen: K: Prijsvragen
	Kansen: K: Stikstofproblematiek
	Kansen: K: Subsidie: MIA
	Kansen: K: Subsidie: SDE++
	Kansen: K: True Pricing
Resources	
	Kansen: K: Boseigenaren
	Kansen: K: Certificering
	Kansen: K: Energie
	Kansen: K: Grondstoffen
	Kansen: K: Grondstoffen: Cement
	Kansen: K: Grondstoffen: Hernieuwbaar
	Kansen: K: Grondstoffen: Hybride
	Kansen: K: Hergebruik
	Kansen: K: Hoogwaardig gebruik
	Kansen: K: Klimaat
	Kansen: K: Klimaatverandering
	Kansen: K: Landbouw

Measure Codes Categorised as:	
Category	*Code*
Development and Growth	
	Acties: A: Markt: Continuïteit
	Acties: A: Markt: Hollistische prijzen
	Acties: A: Opschalen
	Acties: A: Opschalen: Zaagcapaciteit
	Acties: A: Push en Pull
Expertise	
	Acties: A: Voorbeeldprojecten
	Acties: A: Innovatie
	Acties: A: Innovatie: Bouw
	Acties: A: Innovatie: Recyclen
	Acties: A: Innovatie: Verwerking
	Acties: A: Onderwijs
Knowledge and Information	
	Acties: A: Financierders
	Acties: A: Informeren
	Acties: A: Faciliteren
Policy and Government	
	Acties: A: Beleid
	Acties: A: Beleid: CO2
	Acties: A: Beleid: LCA
	Acties: A: Beleid: MPG
	Acties: A: Beleid: Sancties
	Acties: A: Beleid: Subsidies
	Acties: A: Incentives
	Acties: A: Ambitie
	Acties: A: Acties
Resources	
	Acties: A: Certificering
	Acties: A: Duurzaam Beheer

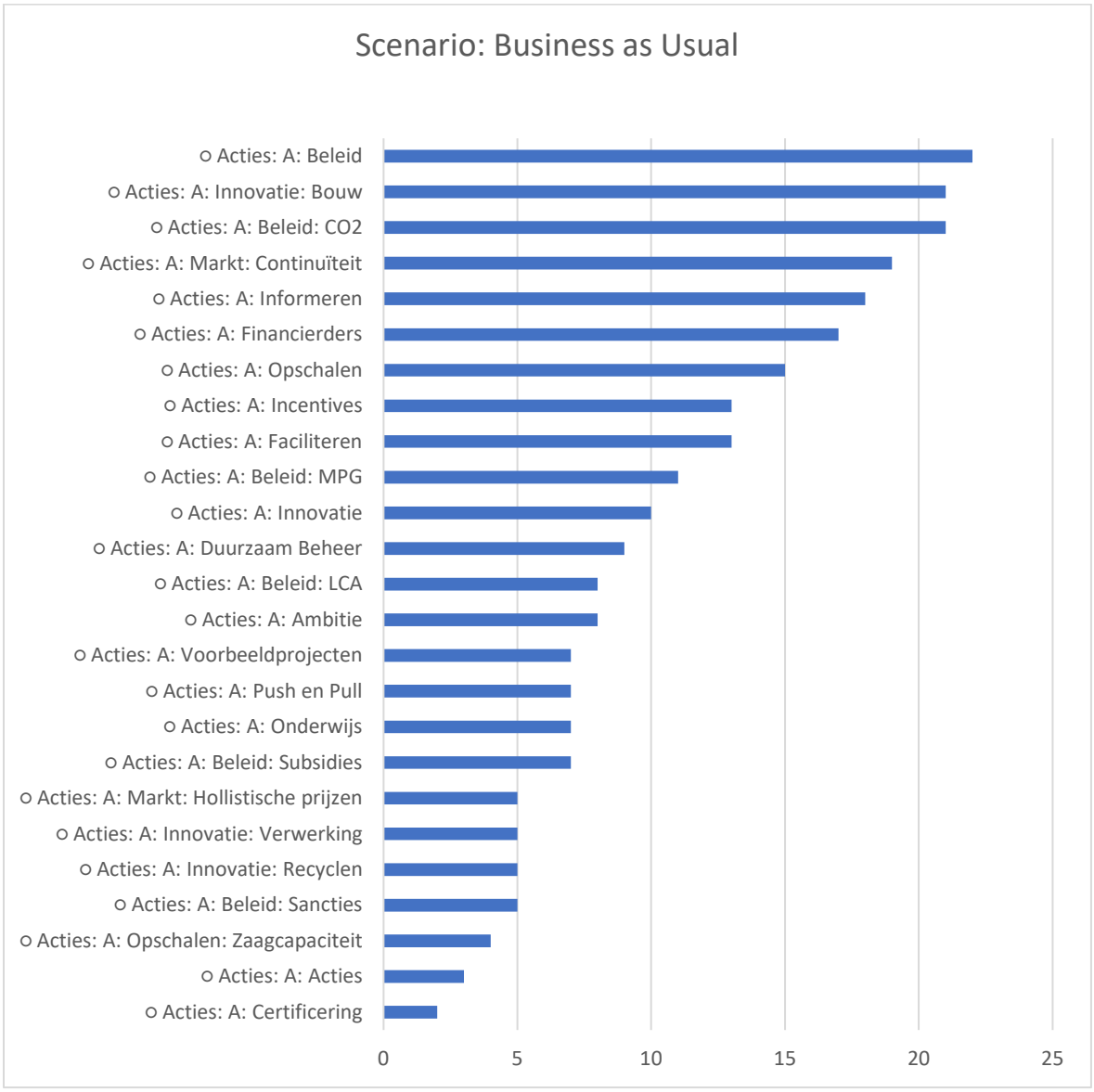
2. Code Categories per scenario

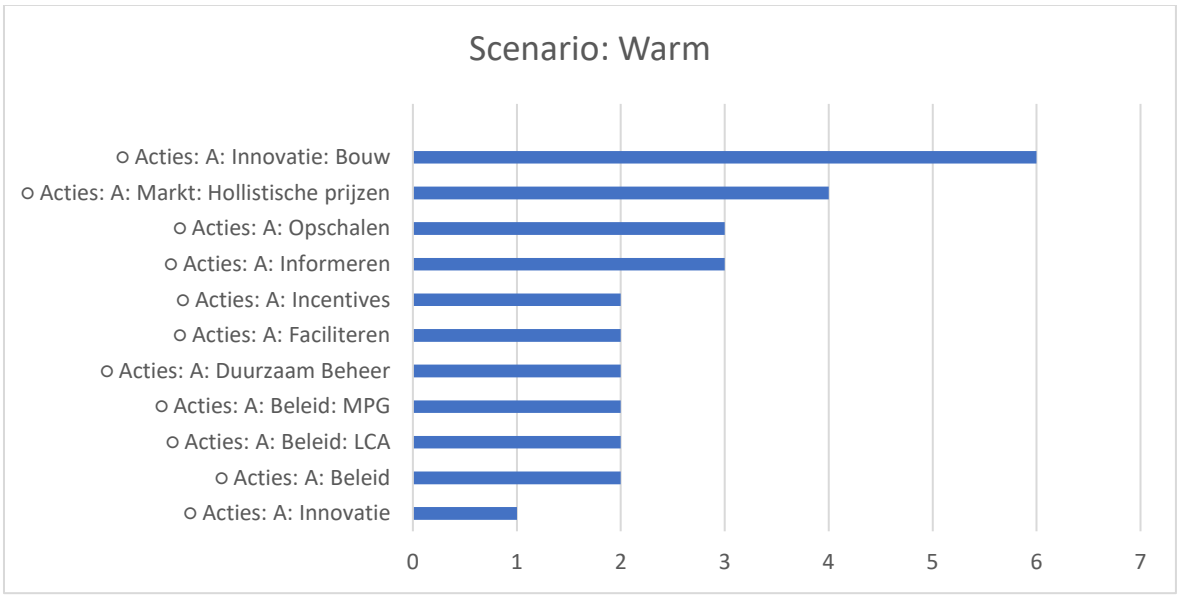


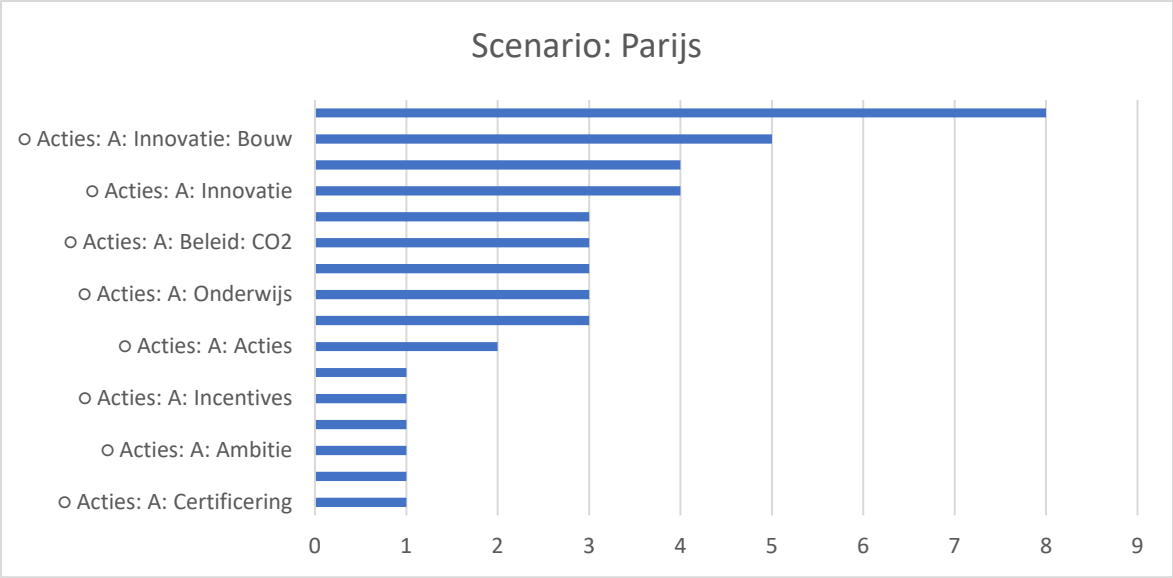




3. Codes associated to Measures







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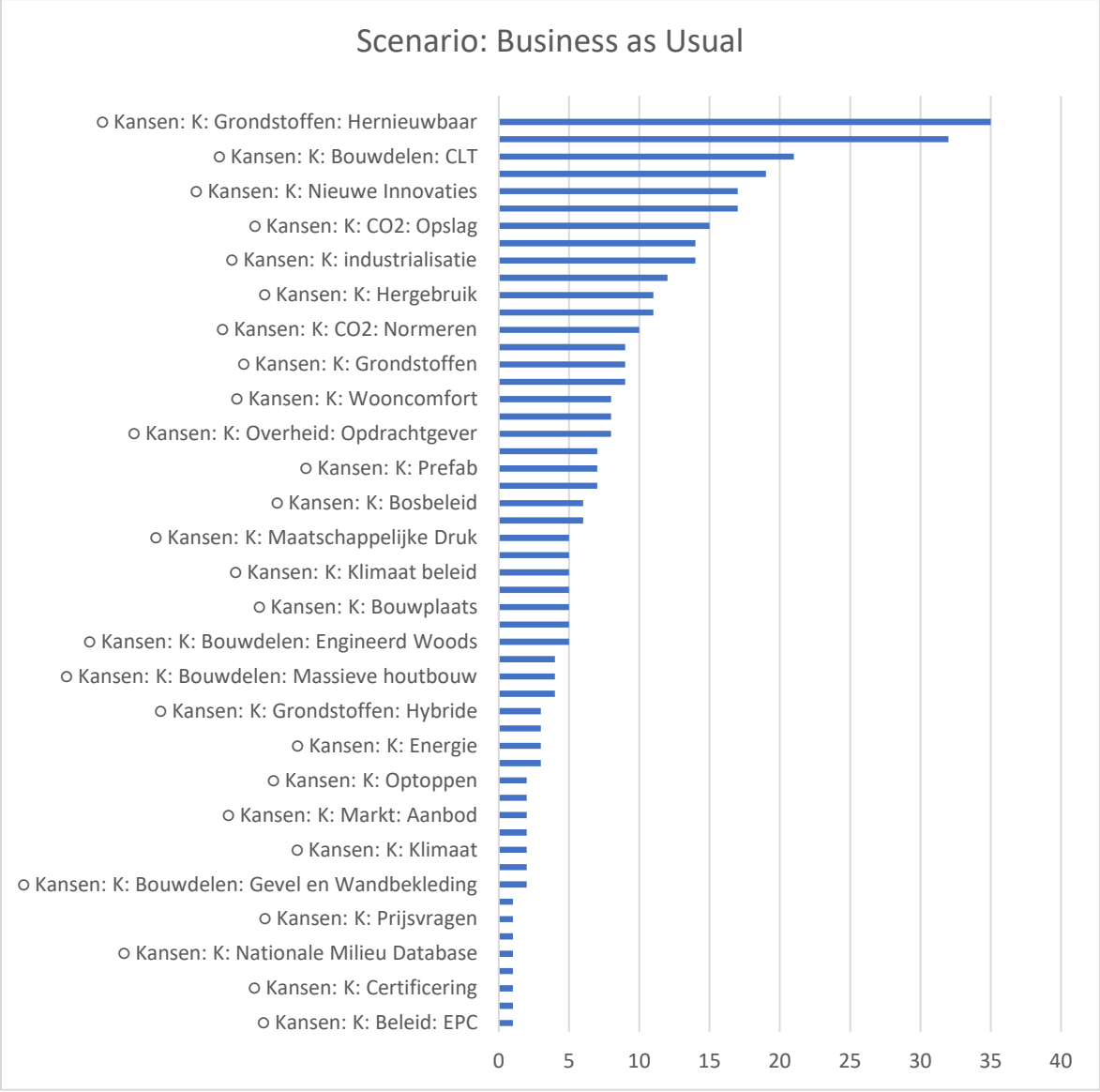

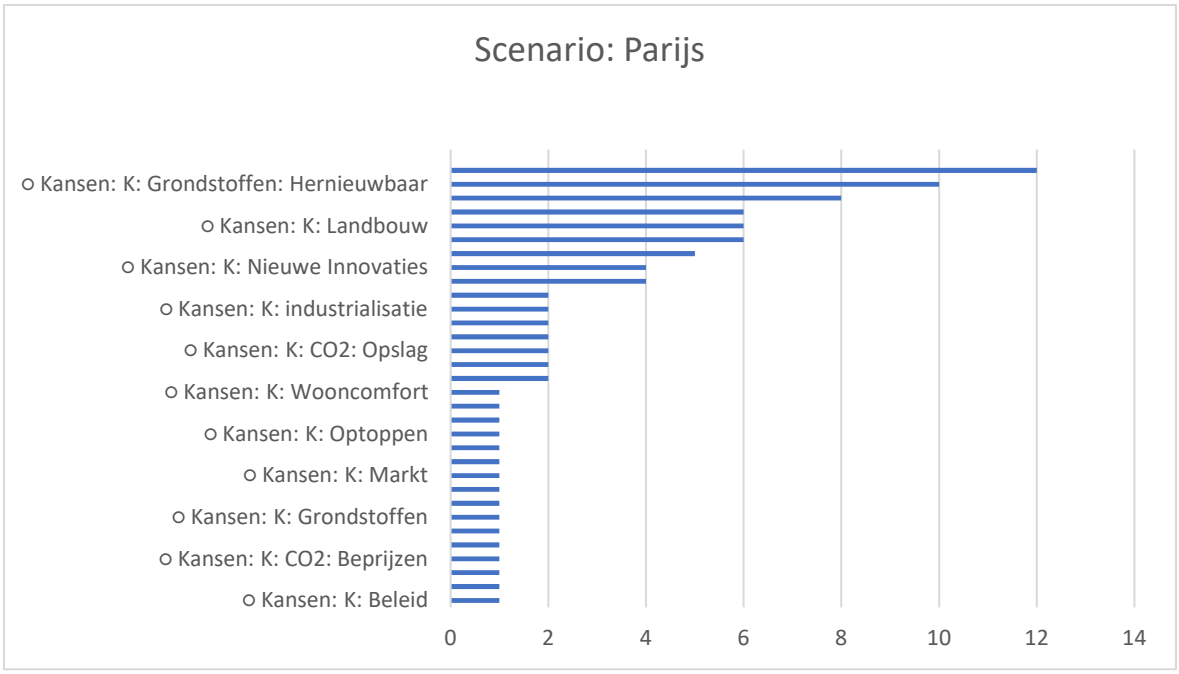
Scenario: Parijs
Kansen: K: Grondstoffen: Hernieuwbaar
Kansen: K: Landbouw
Kansen: K: Nieuwe Innovaties
Kansen: K: industrialisatie
Kansen: K: CO2: Opslag
Kansen: K: Wooncomfort
Kansen: K: Optoppen
Kansen: K: Markt
Kansen: K: Grondstoffen
Kansen: K: CO2: Beprijzen
Kansen: K: Beleid
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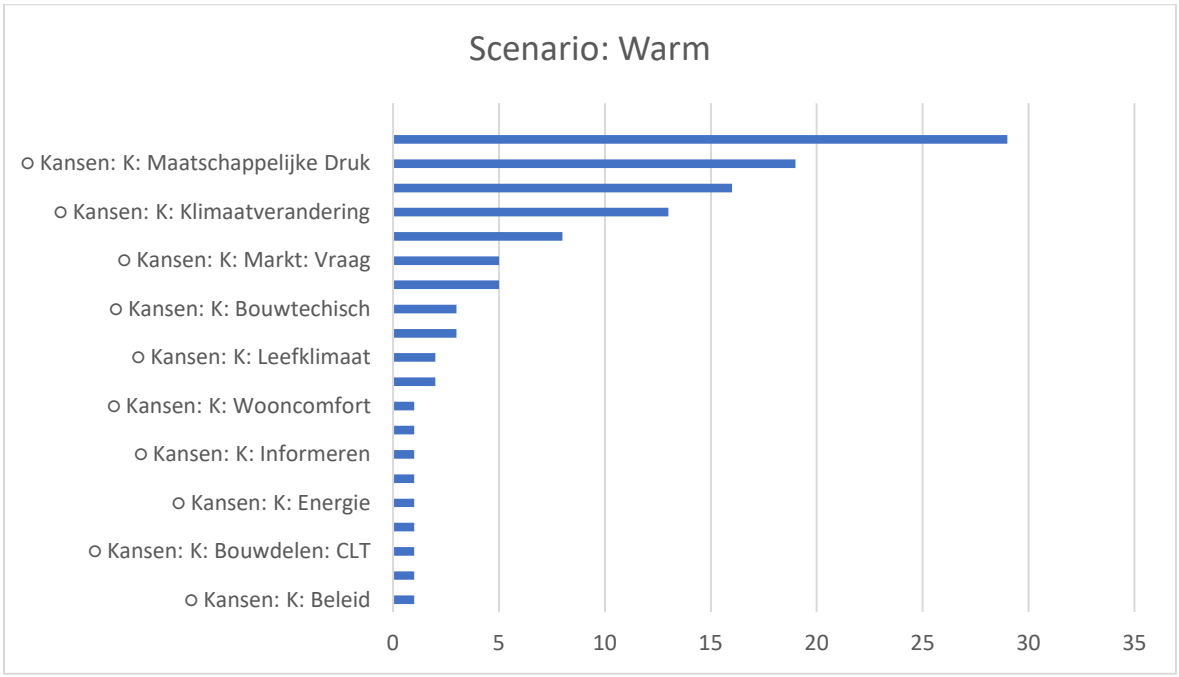
Scenario: Warm
Kansen: K: Maatschappelijke Druk
Kansen: K: Klimaatverandering
Kansen: K: Markt: Vraag
Kansen: K: Bouwtechisch
Kansen: K: Leefklimaat
Kansen: K: Wooncomfort
Kansen: K: Informeren
Kansen: K: Energie
Kansen: K: Bouwdelen: CLT
Kansen: K: Beleid
0
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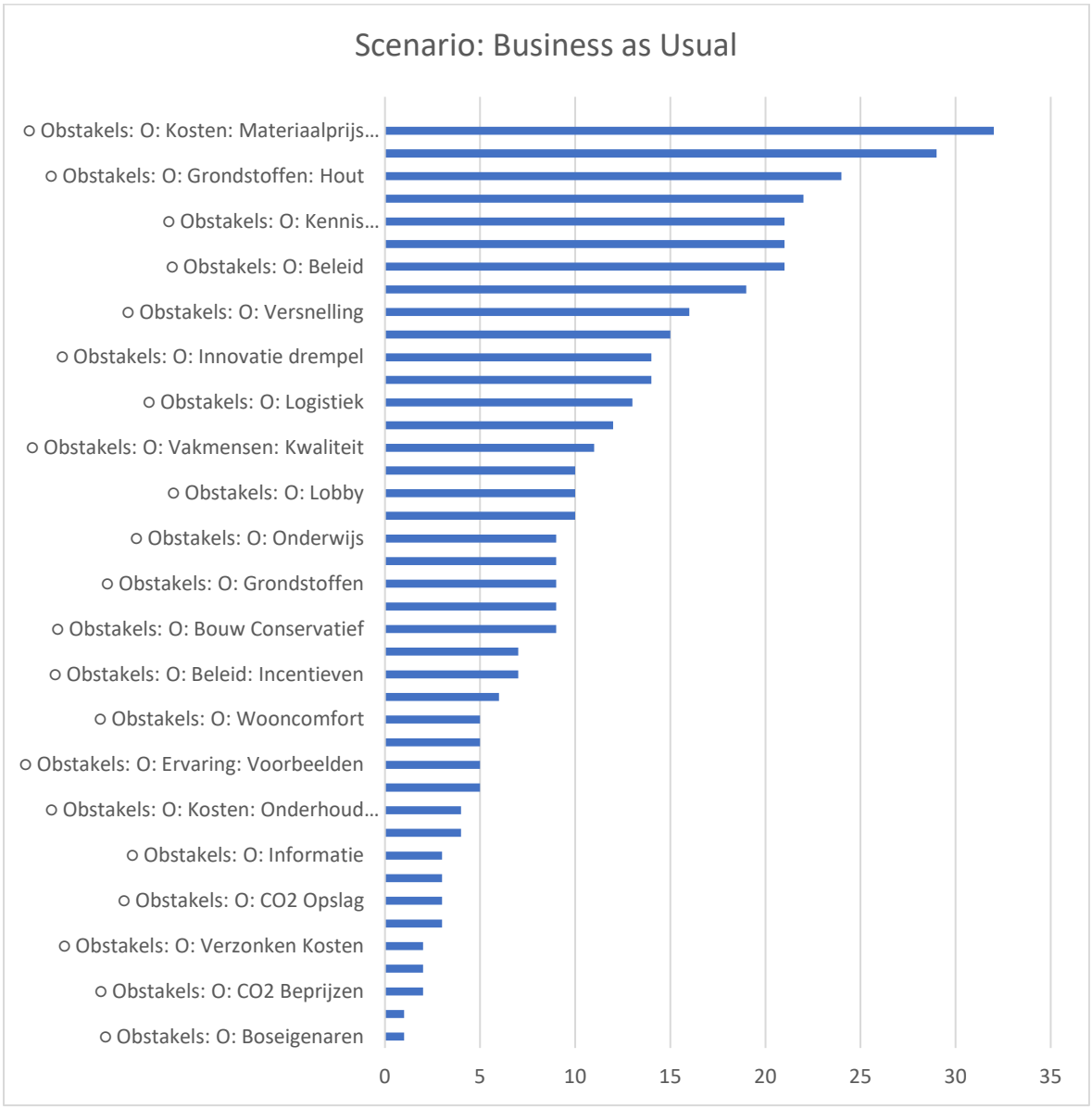
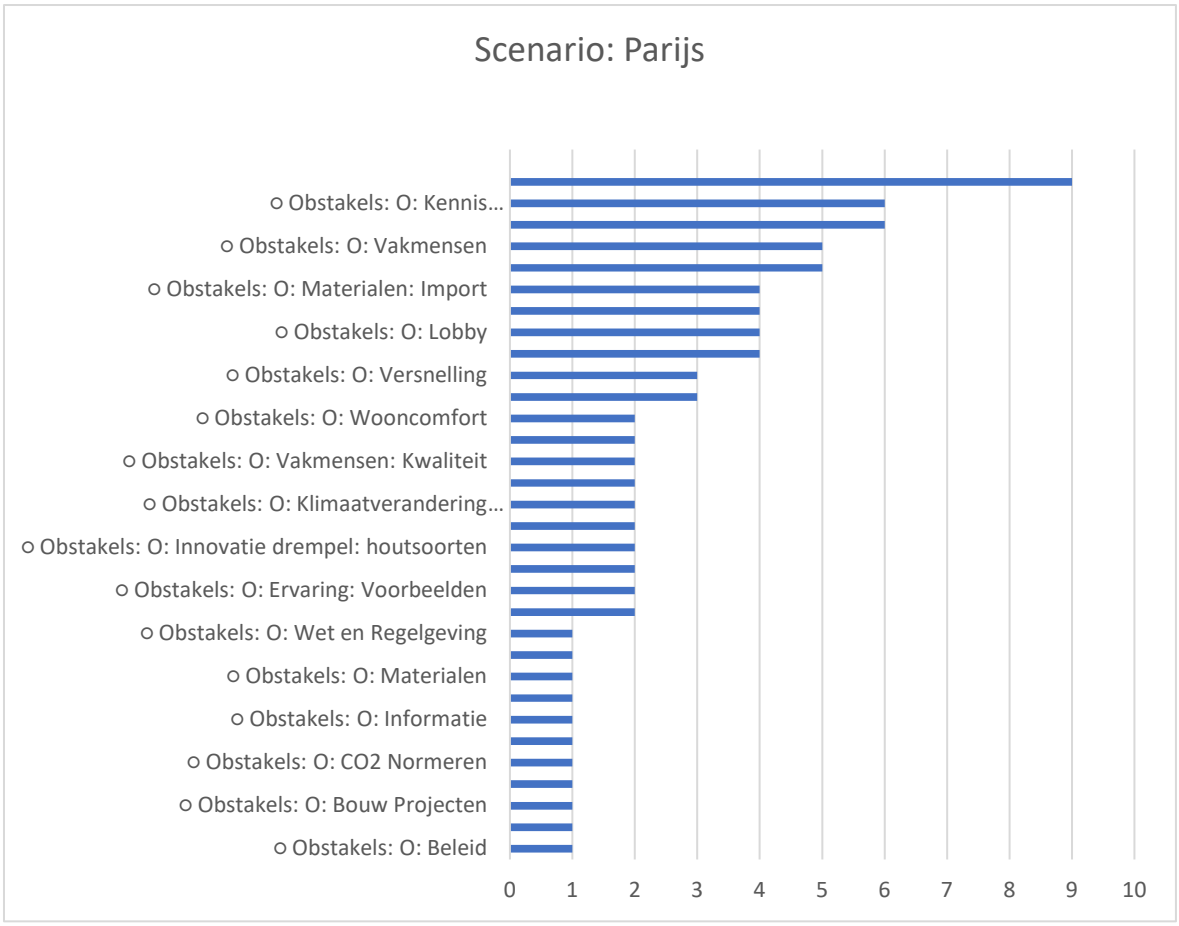
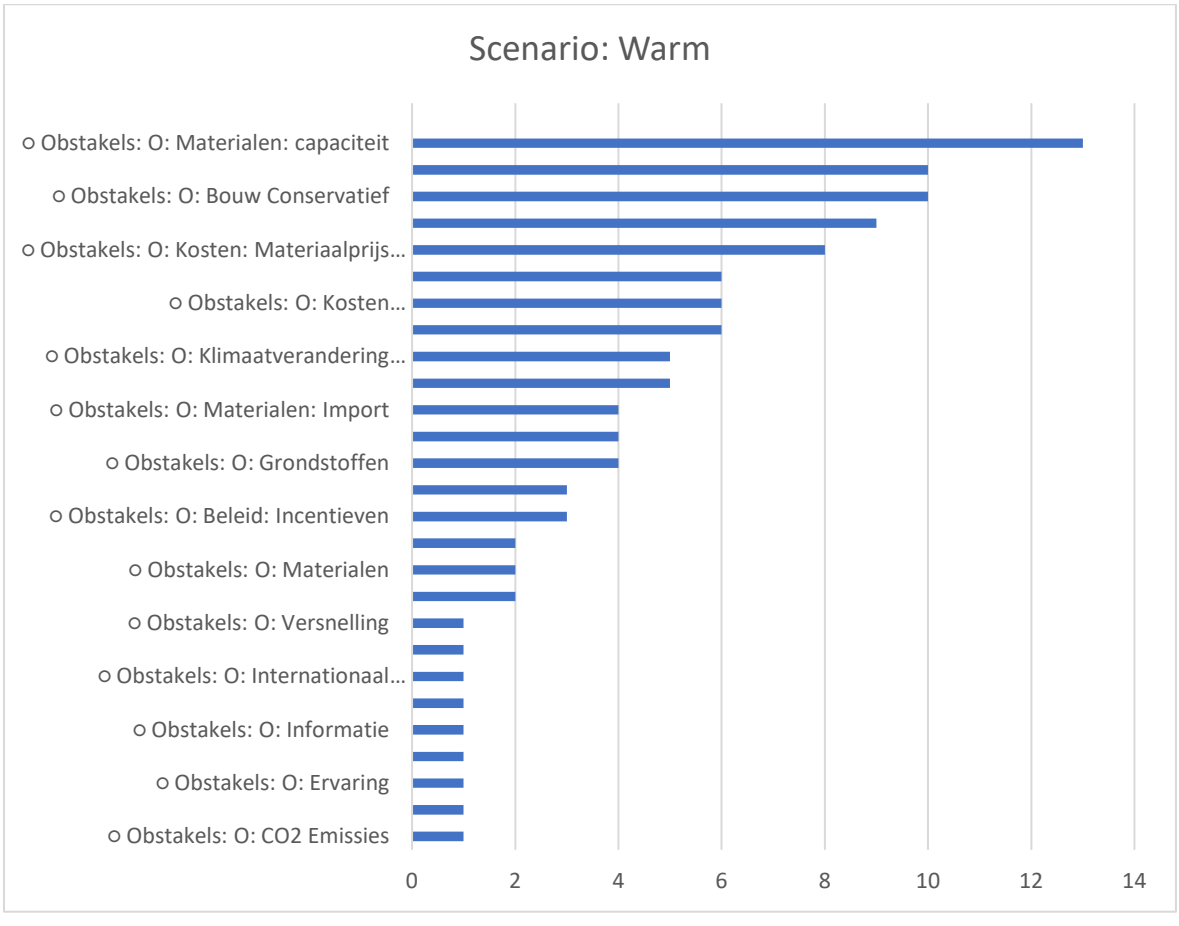
10
15
20
25
30
35

5. Codes associated to Obstacles




Scenario: Parijs
Obstakels: O: Kennis...
Obstakels: O: Vakmensen
Obstakels: O: Materialen: Import
Obstakels: O: Lobby
Obstakels: O: Versnelling
Obstakels: O: Wooncomfort
Obstakels: O: Vakmensen: Kwaliteit
Obstakels: O: Klimaatverandering...
Obstakels: O: Innovatie drempel: houtsoorten
Obstakels: O: Ervaring: Voorbeelden
Obstakels: O: Wet en Regelgeving
Obstakels: O: Materialen
Obstakels: O: Informatie
Obstakels: O: CO2 Normeren
Obstakels: O: Bouw Projecten
Obstakels: O: Beleid
0 1 2 3 4 5 6 7 8 9 10


Scenario: Warm
Obstakels: O: Materialen: capaciteit
Obstakels: O: Bouw Conservatief
Obstakels: O: Kosten: Materiaalprijs...
Obstakels: O: Kosten...
Obstakels: O: Klimaatverandering...
Obstakels: O: Materialen: Import
Obstakels: O: Grondstoffen
Obstakels: O: Beleid: Incentieven
Obstakels: O: Materialen
Obstakels: O: Versnelling
Obstakels: O: Internationaal...
Obstakels: O: Informatie
Obstakels: O: Ervaring
Obstakels: O: CO2 Emissies
0 2 4 6 8 10 12 14