Establishing a Market for Secondary Raw Materials

- In the context of Danish Road Construction

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Summary

The problem area of this thesis surrounds the depletion of natural raw materials. It addresses the environmental, social, and economical issues surrounding the depletion and the intensity of excavation in Denmark. This includes loss of biodiversity, noise- and air pollution and CO2e emissions from excavation, transport, and processing. The aim of the thesis is to mitigate this through reuse, recycling and prevention or substitution. Reaching this goal requires the establishment of a market for secondary raw materials that can circulate, that performs similarly to the market for primary raw materials, but functions differently. The problems with establishing such a market are many but is in the thesis narrowed down to four areas of attention, in which barriers lie. The four areas of attention and their main barriers are as follow:

- Procurement: Few criteria and low demand for high utilization value of secondary raw materials. Lack of GPP criteria as incentives adopted in Danish context.
- Policies: Lack of ambition, vision, and guidance from government. Current Danish incentives do not provide enough motivation.
- Risk: Market actors as well as public developers are risk-averted. The nature of small margins and rigidity of the sector contributes to this. Current incentives do not yet encourage risk-taking.
- Valuation: Perceived low utilization value of secondary raw materials means that primary raw materials remain the preferred option, even if they cost more. This also ties in with risk-aversion.

To address this problem, desk research, participant observation and interviews are used to uncover what changes in the four areas are needed. Transition theory is applied to the four areas, to highlight the complexity and interconnectedness. Valuation is also discussed on the basis of the theory of economic ecology and the de-growth perspective.

The main conclusions of the thesis are that adjusting or discussing the Willingness-to-Pay in the Danish Road Directorate is imperative to ensure better utilization of their CO2 performance-based procurement. This discussion is regarded as highly political, and therefore also draws on the need for changing how traditional cost-benefit models are calculated in Danish government. A broader ecological economist perspective should be implemented, to account for avoided emissions, biodiversity loss, social implications etc. Another conclusion is that any frameworks that mitigate risk-aversion will be beneficial to push the transition in the construction sector, some of which are roll out of CE-markings, public demand, risk funds etc. The overarching conclusion regarding how the Danish Road Directorate can facilitate a market for secondary raw materials is, that they must learn from, specifically Dutch, green public procurement and secure better adoption of these tools and criteria in their organization. But on a grander scheme, government understandings of valuation must change, to allow for higher Willingness-to-Pay which in turn allows for better environmental competing in tender contests where CO2 performance, preferably in the future a more holistic approach, is what determines the winning bidder.

Preface

The motivation behind the chosen research area stems from the author's previous semester projects and internship at Center for Offentlig-Privat Innovation. Previously, many of the author's drawn conclusions, in semester projects, have been that actors in the construction sector must take certain actions in other to combat climate impacts and emissions from the sector. The aim of this thesis is to dive further into what measures can allow for actors in the construction sector to take the wanted action.

Thank you to supervisors Arne Remmen and Stig Hirsbak for the feedback and guidance.

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Indhold

Glossary of terms

The following glossary defines keywords and elaborates on them to form a delimitation for the thesis. A translation to the Danish word is also added for context, as the thesis is written from a Danish perspective.

Raw materials: (Råstoffer) The virgin raw materials that are sand, stone and gravel.

Secondary raw materials: (Sekundære råstoffer) Materials that are reused or recycled to supplement or substitute virgin raw materials. This thesis uses 'reuse' in the definition, contrary to the EU definition, because reuse in civil engineering works is regarded as using pre-used (secondary) materials. Reuse is necessary to consider in the definition of secondary raw materials, as reused materials do not have the same perceived value as virgin materials, even though possibly having the same structural integrity.

By-products: (Restprodukt) The residual excess product from, typically, industrial processes such as burning or processing.

Civil engineering works: (Anlægsprojekt) Infrastructure construction works. This thesis focuses on roads, but reused and recycled materials could also stem from utility construction, railroad construction etc.

Reuse, **recycling,** and **substitution**: (Genbrug, genanvendelse og erstatning) Refers to materials that are used again for the same or another purpose, materials that have been processed in various ways to be used again and materials, or amounts of materials, that have been replaced by others (fx by-products).

Secondary market: (Sekundært marked) A market that essentially enables circular business models, that specifically reuse, recycle, and substitute, to profit and thrive.

Incentive: (Incitament) An instrument (financial, practical, competition based, etc.) that is used to promote or prevent certain market movements.

Policies: (Politikker) Rules or guidelines that influence, among others, market movements. Policies in this thesis are of legislative nature and encompasses plans and strategies.

Circular letters: (Cirkulærer) An administrative instruction or order that applies to authorities and often contains rules for lower hierarchical institutions (Justitsministeriet, 2023)

Statutory orders: An order issued by a governing authority that contains and elaborates on rules which are binding to citizens and authorities. (Folketinget, 2023)

Valuation: (Værdiansættelse) The actual or the perceived value that a product has based on several factors, such as previous usage, processing needs, risks involved in its usage, etc. Valuation also encompasses modern environmental considerations such as, CO2-savings, total cost of ownership, avoided emissions.

High/Low utilization value: (Høj/Lav brugsværdi) The value of the usefulness of a product. In this thesis the degree of utilization value is based on project types (See figure 2).

Procurement and **tender practice**: (indkøbs- og udbudspraksis) Refers to the habitual ways of performing procurement and tenders. A practice is a form of doing, that can be predicted.

Circularity: (Cirkularitet) The action of preventing or reducing waste by, among others, reusing, recycling, and substituting. Circularity is used in this thesis to encompass the actions that enable a circular economy.

Developer: (Bygherre) The thesis takes point of departure in public developers. Developers are the instigating and paying actor in civil engineering works. In conjunction with procurement and tenders, they are the contracting entity.

Contractor: (Entreprenør) The executing actor in civil construction works.

Counseling firm: (Rådgivningsvirksomhed) The projecting and advising actor. Often also the actor in charge of the design of civil engineering works.

1. Review of the problem area

The existing and increasing threat of climate change is becoming more apparent today. The impacts of irresponsible overconsumption created by linear business models is, among others, felt by a multitude of market actors and hastily requires effort and action to secure a sustainable transition (IPCC, 2022). This report takes point of departure in the issues created by natural raw material depletion in Denmark caused by linear construction.

1.1. Correlation between raw materials depletion and construction activity

As 70 pct. of natural raw materials for construction (sand, gravel, and stone) are utilized for infrastructure and road materials, a narrowed focus to the Danish civil engineering sector can be applied when problematizing raw materials depletion. Regarding society's increasing development and expansion of civil engineering works, the Danish regions estimate that by 2035 there will be a demand for approximately 40 million m3 of natural raw materials for construction, mainly in the capital region. This level of extraction is estimated to last for 46 years before fully depleting (COWI, 2017). This is without taking raw material quality and other environmental and spatial issues into account. Table 1 shows the raw material consumption of more general project types in Denmark except for one-of-a-kind projects such as Fehmarnbelt tunnel and Lynetteholmen. In general, the construction of roads, especially high-speed roads, are the biggest draw on raw materials per kilometer.

Raw material consumption pr. km of project type

Project type	m3 pr. km
Construction of four lane motorway	33.800
Construction of slower motorway (motortrafikvej)	26.600
Expansion of motorway with two lanes	25.500
Construction of railway	8.700

Table 1 (SWECO, 2016)

The capital region expects, in 2035, a 40 pct increased demand compared to 2012. With this expected demand, the Danish regions have calculated that, with the current planned out areas, natural raw materials for construction will run out within 14-43 years. (Copenhagen Economics, 2017) The reason for the wide span is due to the difference in raw material occurrence in the five regions. Some Regions are already experiencing this depletion as it becomes increasingly

difficult to identify new digging areas to meet the demand. Thus, three areas of action have been pointed out the several regions:

- Save the raw materials by working towards utilization of alternatives to virgin raw materials.
- Promote reuse of road and construction materials.
- Reuse surplus soil.

(Region Sjælland, 2021)

Yearly potential for secondary raw materials

Secondary source	Construction waste and fly ash	Soil	Harbour and shipping lanes	**Total potential**
Amount, mio. m3	2.2	3.7	3.4	**9.3**

Table 2 (COWI, 2017)

The potential in extraction of secondary raw materials is shown in Table 2, however, the amounts are highly inaccurate due to lack of data showing the material loss during processes such as demolition, cleaning, and sorting. It is important to differentiate between extraction and consumption, as export and import skews the statistics. However, with an extraction of 33.750 mio. m3 in 2021 (Danmarks Statistik, 2023) the potential secondary raw materials could cover approximately 28 pct. of Danish extraction. Region Sjælland aims at covering 20% of consumption with secondary materials by 2032 and Region Hovedstaden by 2030 (Region Sjælland, 2021) Whilst this is not fully circular yet, it can help extend the remaining raw materials. As most raw materials are utilized directly in civil engineering works or for concrete production, this invariably puts the construction and civil engineering sector as the main area that needs to transition towards circular management and utilization of natural raw materials. However, as construction activity correlates to BNP (see Figure 1), it is difficult to imagine lower demand, as Danish BNP is overall on the rise (Danmarks Statistik, 2023).

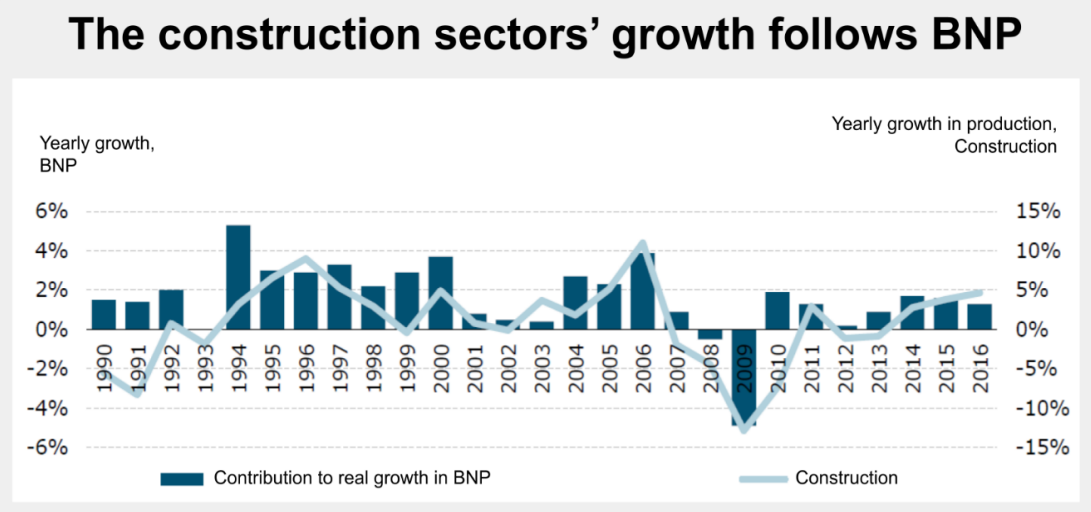


Figure 1 (Copenhagen Economics, 2017)

1.2. The impacts of raw material depletion

Adding to the urgent problem of raw materials depletion are also several other issues that affect citizens and actors throughout the value chain. This is due to the very physical nature of raw materials extraction as well as new pressures being applied on the linear business models. These issues are among others:

- Planning and conflicts of interests
- Citizens
- Biodiversity and environmental protection
- Transport and CO2
- Costs

There are several other interests that make the regions' natural raw materials plans difficult to carry out. The spatial planning of Denmark involves conflicts with many different interests, such as nature, energy production, city development, drinking water etc. Teknologi Rådet calculates that 130-140 pct. of the Danish area is already planned for if Denmark is to fulfill its expected future political visions and developments. (Jørgensen, Arler, & Sørensen, 2017). In other words, there is a battle between the interests and the natural raw materials plans are not to contravene these. Lastly, the extraction areas are increasingly being located closer to densely populated areas.

This creates conflicts between regions, municipalities, the extraction firms, and the citizens. GEUS (The Danish national geological research center) reports, from the extraction firms, an increased involuntariness from the citizens as well as an increase in complaints. (Rosholm, Kalvig, & Fold, 2016) These citizens are impacted by the noise and air pollution coming from extraction areas, accompanied by the streams of heavy traffic.

The heavy traffic caused by trucks is, other than having a sensory impact, also adding the CO2-emissions from the extraction industry. As depletion occurs, and demand rises, especially in the populated areas, many natural raw materials are exported across regional borders. In 2015 trucks were driving 260 million kilometers and it is estimated that about half of those trips were with empty loads as the trucks returned to the extraction area.

The cost of natural raw materials is also affected by the increased transport. The further a truck must travel, the higher the price of natural raw materials pr. ton is. It is estimated, in 2017, that the transport price is 1 DKK pr. ton pr. kilometer traveled. The contractor or developer thus pays for the natural raw materials and the transport. This could function as an incentive to promote more localized usage of available raw materials. However, many actors in the value chain still follow their usual patterns, which seem easier and cheaper, as virgin raw materials are prioritized over secondary raw materials.

Even though actors across the value chain are impacted by the natural raw materials depletion and the related issues, they are still not fully transitioning toward alternative actions. There are

several answers to why the transition is not occurring or is slow at best, but a big reason is the barriers in creating a market that encourages utilization of secondary materials.

1.3. Challenges to utilizing secondary raw materials in civil engineering works

Raw material depletion, societal conflicts, rising CO2-emissions from transport and the increasing costs of handling are reasons why a market that supports utilization of secondary materials is in dire need. The benefits of creating a secondary raw material market are plentiful. Raw material depletion could be decelerated or even prevented due to circulation, reuse and recycling, CO2-emissions could drop significantly due local circulation with minimal transport, and costs could also drop in comparison to the handling of virgin raw materials. The benefits are clear, but there are several challenges that inherently obscure the path towards a successful market establishment. These are, among others, found to be:

- Low valuation and waste terminology
- No standardized quality or production flow
- Quantities and storage
- Liability and processing
- Geography and market form
- Planning, handling and timing

The following section unfolds these challenges and refers to how the contemporary market operates and is established.

1.3.1. Low valuation and waste terminology

As the terminology hints towards, ‘secondary’ raw materials inherently have a lower perceived value than primary virgin raw materials. Secondary raw materials are considered waste from construction processes, excess raw materials from material production or raw materials gathered from renovations. The low valuation is likely given due to the degradation of the material, the processing that it needs and in general the additional workload of handling it, as well as the aforementioned challenges. It falls under the category of high entropy with low valuation. (Bendsen, Førby, Bakas, Kampmann, & Andersen, 2019). Much of building construction waste is processed and used for civil engineering works, such as crushed concrete in road fill. Certain civil engineering works (with the exception of bridges and tunnels) are often perceived as easier to utilize lower valued raw materials. This is visualized in Figure 2 as an interpreted waste hierarchy but based on project types. Here, the most valuable raw materials and materials are used in project types at the top of the hierarchy and the more polluted or less valued raw materials are used towards project types at the bottom. But when civil engineering works are constructed or renovated, there are no ‘lower grade’ projects to send the excess ‘waste’ raw materials to. Thus, civil engineering works are essential to close to material loops, as they often are at the end of the value chain.

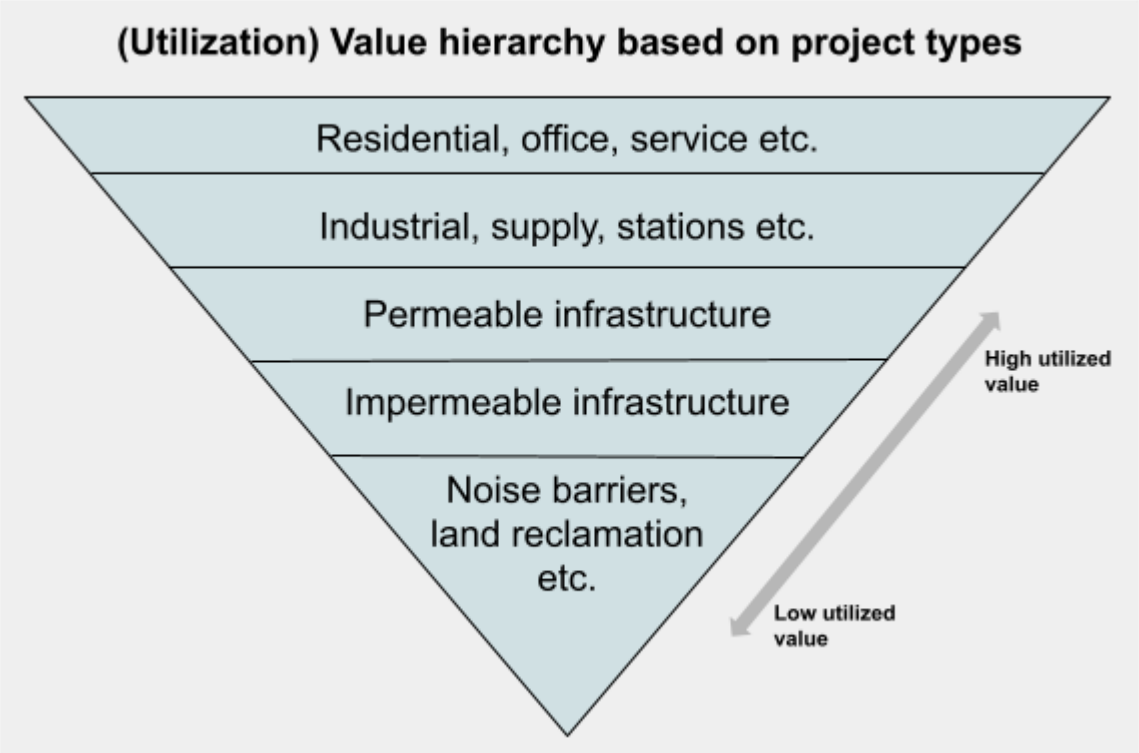


Figure 2 (Self-created)

1.3.2. No standardized quality or production flow

Secondary raw materials originate from renovations, demolition and from construction activities, thus they have a less foreseeable outflow compared to virgin raw materials that are produced at a steady rate to meet demand. Adding to this, different methods of renovating, demolishing, and constructing, may influence the grade of the secondary raw materials, resulting in a wider range of variety between the secondary raw materials. (Bendsen, Førby, Bakas, Kampmann, & Andersen, 2019) This is contrary to virgin raw materials that can be ordered at different standardized sizes, grades, etc. Due to business models surrounding production and delivery of virgin raw materials, the product line is standardized making the product consistent and reliable.

1.3.3. Quantities and storage

Unlike building construction materials, raw materials for civil engineering works are often heavy materials in large quantities which makes transport and storage a challenge. Large storage facilities have higher costs, and some raw materials may need special storage to avoid contamination. Some developers prefer to use external companies that specialize in storage and processing of large quantities of raw materials.

1.3.4. Liability and processing

The use of external companies for storing and processing aids in the overall handling of secondary raw materials as some liability, admin, and workload is shifted to actors that are specialized in that field. Liability issues arise from both from the perceived low value and

accompanied lower performance of secondary raw materials. They also arise from a broad lack of experience utilizing secondary raw materials, as these are often associated with concerns of contamination, higher degradation rates and lower load bearing capacities. (Bendsen, Førby, Bakas, Kampmann, & Andersen, 2019)

These concerns also lead to more processing to improve their performance, in some cases, to match virgin raw materials. Processing adds to the overall costs and therefore, as therefore renders utilization of secondary raw materials redundant. Figure 3 visualizes the added transport also needed in the processing, which is also costly. The extra variables in the secondary raw materials scenario makes the primary raw materials scenario more attractive from a traditional business standpoint of reducing time and cost.

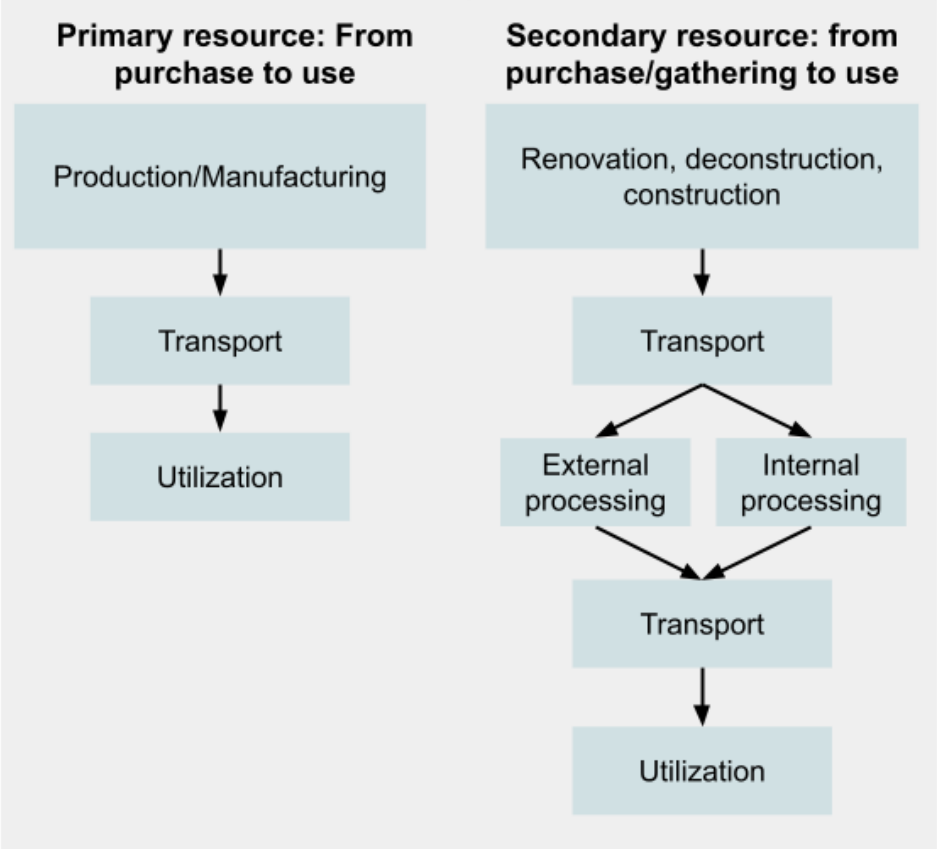


Figure 3 (Self-created)

1.3.5. Geography and market form

The geography of secondary raw materials occurrences is also to be considered when mentioning the added transport. As mentioned earlier, the cost of transport is 1 DKK pr. ton pr. kilometer traveled, so the travel needs to be reduced to make the business model viable. Thus, there must be a limit to how far it is viable to travel to obtain secondary raw materials compared to purchasing primary raw materials. This likely results in very local markets being established, leading to a national skewed competition. This can already be observed to some degree through the pricing of external raw materials processing and trucking companies (NORRECCO, 2023).

1.3.6. Planning, handling, and timing

Civil engineering works are often subject to tight schedules and require large capital. Thus, planning for secondary raw materials use that often requires more time and transport, is seen as a liability, and therefore not prioritized.

In terms of time, the use of secondary raw materials depends on the occurrence of them. If a project needs more than initially thought, or at an earlier stage than planned for, the lack of availability can be an obstacle. It is therefore difficult to plan for the usage, due to the earlier and much more attentive planning needed.

1.4. The need for engaging the challenges

To establish a healthy market for secondary raw materials the need to tackle the above challenges is the main task at hand. The following section investigates some of the initiatives, tools and mechanisms that are brought forward to overcome the aforementioned challenges.

1.4.1. Valuation - The waste hierarchy

The Waste Framework Directive 2008/98/EC (WFD) is the cornerstone of EU waste legislations as it brought forth the visualization of a hierarchy of waste that illustrated what the most favorable and least favorable management of waste was at the time. It is currently still the framework for waste and subsequent valuation of what is regarded as waste. As seen on Figure

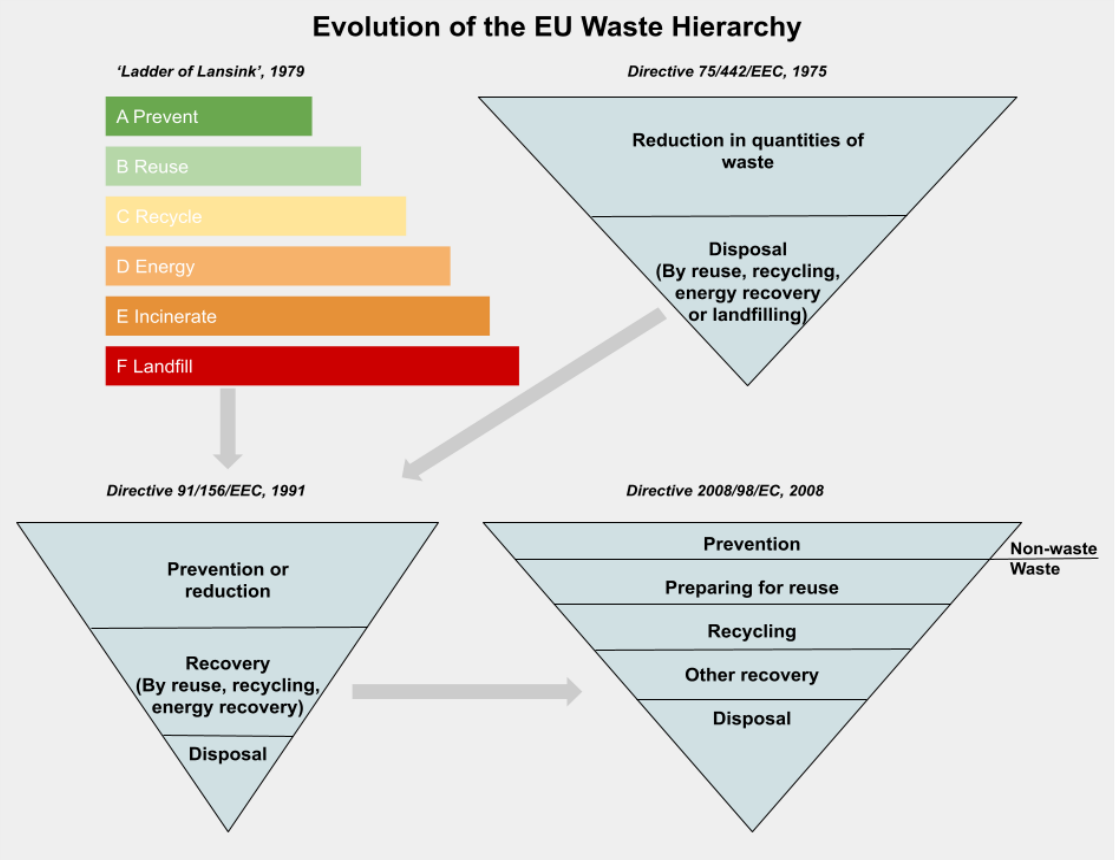


Figure 4 Reinterpreted figure based on (Zhang, et al., 2022)

4, the waste hierarchy is based on several past iterations and has also, through further research in the field, been subject to consequent interpretations.
The WFD created this approach to tackle the increasing waste stream, especially construction and demolition waste (CDW). Most noticeably is the evolution towards defining what is considered waste and what is considered non-waste. This distinction is important as each Member State has different interpretations of what terminology and methods are used for waste and non-waste, which is also a reason why European CDW data is unreliable in terms of comparison (Wahlstrom, et al., 2020).

This distinction of waste and non-waste, paired with classifications of pollutants in recycled raw materials, can inhibit recirculation in several types of construction projects and adds to the problem of low valuation of secondary raw materials. As Figure 4 shows, everything below prevention is considered waste, which rules out utilization of a lot of perfectly recyclable raw materials and materials. Several actors handling soil state that they find it difficult to determine clean, slightly polluted, and polluted soil when reporting (NIRAS, 2017).

The Danish waste executive order proposes several definitions of waste for recycling and waste for recovery, of which the definition of what types of projects are encompassed by recovery is broad. The term recovery in the Danish context almost sounds good, but as Figure 4 shows, it is positioned low in the EU waste hierarchy. Several actors report different understandings of the terms recycling and recovery even though they are defined in the waste executive order. Further they report that municipalities and the industry rarely distinguish between these two terms (NIRAS, 2017). When reading the Danish waste statistics from 2019, the statistics are largely written as recovery versus disposal, which gives 85 pct. recovered soil (unpolluted and polluted) a positive connotation (Madsen, Kiilerich, Andersen, Andersen, & Sander, 2019). Most of this soil is used for noise barriers, which in this report is perceived as poor utilization of raw materials. Even though the recycling rate of CDW is high, it is estimated that the utilization is of a low value (See Figure 2).

Determining what is waste/non waste and ensuring clear definitions that are followed in practice has an increasing influence on the valuation of raw materials. The waste hierarchy is thus a determinator in what raw materials are considered of high value and low value, which is currently problematic due to the high bar that is set for what is considered waste. There is a need for new forms of perceiving and adding value to construction products and byproducts. End-of-waste (EoW) criteria is one way that EU attempts at thwarting low utilization value of secondary materials that are too early on considered waste. EoW criteria seeks to clearly distinguish waste from secondary products and thereby promote high value utilization (ECOS; EBB, 2021).

1.4.2. Risk - Buying into a non-existent market

The aforementioned challenges to utilizing secondary raw materials are accompanied by the barrier of risk. Risk occurs when either a contractor, advisor, developer etc. used a material, for example, that is new to a market. There are less experiences to draw from on the market, and

thus reliability, predictability etc. comes into play. Risk is when actors are unsure of quality assurance, additional costs, complicated logistics, durability etc. Traditionally risk is considered a large barrier to any innovation, especially in the construction sector, due to a rigid way of determining return of investment and the continuous availability of cheaper and less risky options.

The initial investments that innovation requires, when for example recycling or reusing secondary raw materials, are high due to non-existing broad market practices and competition that gradually lowers the cost (Bendsen, Førby, Bakas, Kampmann, & Andersen, 2019). The initial investments cover, among other specialized machinery for cleaning, mixing, sorting etc., contracts with companies that often have a degree of monopoly on their solutions, new products used as additives, new practices for workers. These high costs can also be linked with the added time and raw materials needed for new and different tasks.

The manufacturer of secondary products, as well as suppliers are also affected by a high initial investment. Both in terms of their own activities (production, storage, sorting), but also in terms of selling their products (Bendsen, Førby, Bakas, Kampmann, & Andersen, 2019). Their own high initial investments combined with a low perceived value of their products and a low demand makes it difficult to maintain a healthy business model.

Thus, there is a need for financial incentives, such as subsidiary support for creating usable secondary products to combat high initial investments, as well as other economic instruments that could even out the market or even benefit the secondary raw materials market. One study highlights the combination of these financial issues as a main barrier for sustainable development in construction, stating:

"The analysis of the result portrays that the main barrier of sustainable development and sustainable construction is the high cost that is involved in the whole construction process as well as the lack of government financial incentives and rebates." (Khalfan, Noor, Maqsood, Alshanbri, & Sagoo, 2015)

1.4.3. Procurement - Geared towards linearity

Public procurement is indeed influenced also by cost. Award criteria in Denmark are mostly determined on the basis of three principles:

- Price
- Costs
- Relation between price and quality

(Hald, 2023)

Even though there are also sub criteria as well as different ways of defining quality, there is often no mention of sustainability. Traditionally procurement of civil engineering works has

been geared towards low price (Larsson & Gammelsæter, N.D.) The ties in with the substantially lower costs of utilizing readily available primary raw materials, with a high perceived value, that require low or no initial investments due to a well-established market. This risk-averted form of procurement as overtime made it even more difficult for a secondary market to be considered. Thus, there is a need for new eligibility criteria supported by subsequent ambitious tenders, to combat the linear procurement.

Environmental award criteria are increasingly found in public procurement, but can become difficult for procurers to enforce, as there is often little knowledge on what is feasible in the current market. Thus, current environmental award criteria are not specific enough in their needs to be effective or enforceable. (Participant observation)

1.4.4. Policies – Lack of intent and ambition

Policy tools are important as they can influence the established market through incentives as well as through mandatory measures. However, legislation can also have the reversed effect, where rigid frameworks and legalities inhibit circular construction (Larsson & Gammelsæter, N.D.). This is for example the case in legislative waste terminology. Another example is the Danish levy on raw material extraction which was only increased by 29 øre from 2022 to 2023. Acts such as that have no effect on reducing the virgin raw material extraction and is just as much a question of policy ambitions and government attitude. Policies and regulative frameworks need to divert from linear practices towards supporting circular markets. They can be powerful tools to kick start new emerging markets if the incentives are utilized and combined correctly.

1.5. Summary: Four areas of attention

As Figure 5 shows, these are the identified areas of concern. These areas contain several barriers to establishing a secondary market. Even though these four areas are distinguished from each other, they all relate. Not only are they areas of concern, but also areas of opportunity. Engaging the challenges and opportunities in these areas is the key to establishing and supporting a secondary market if certain aspects, as mentioned above, can be tweaked, or radically changed. These are referred to as the areas of attention.

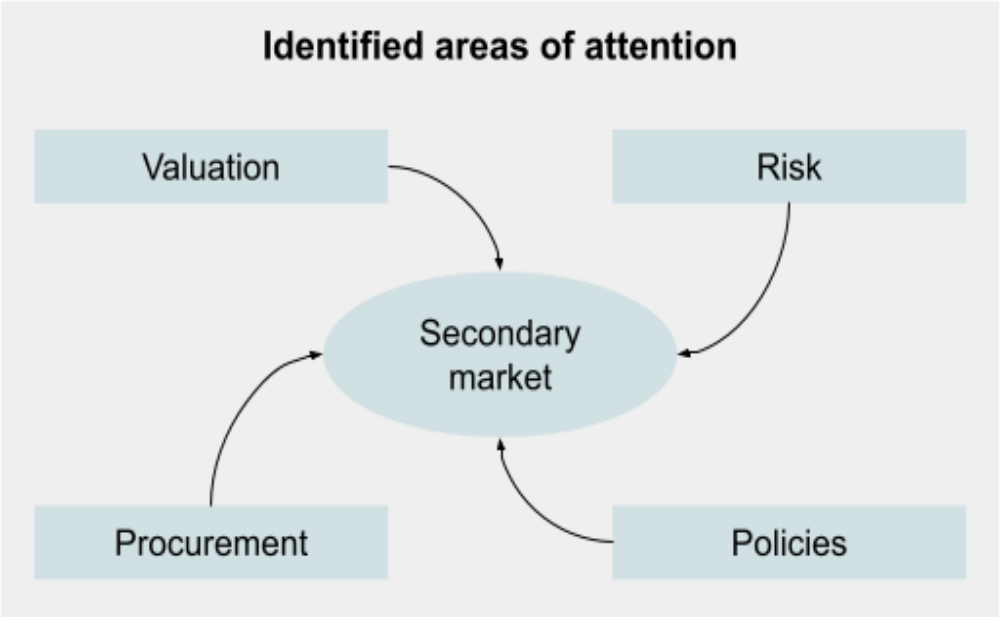


Figure 5 (Self-created)

1.6. Challenges for emerging markets in an incumbent system

Changes must occur in each of the four mentioned areas (see Figure 5). But the construction sector is known for being rigid and opposed to radical change. This construction sector has for many years been dominated by actors supporting linear business models, which in turn have contributed to the depletion of raw materials. To promote more circularity and thus the extension of remaining raw materials a market for secondary raw materials is needed. And by investigating initiatives and their effectiveness in the four areas, a better knowledge of what works best, what accelerates change and how, can be imperative to supporting circular business models in a rigid construction sector.

This thesis takes point of departure in the areas of attention centered around a hypothetical road construction case of 1 kilometer motorway construction by The Danish Road Directorate. By defining procurement and policy strategies on road construction and discussing alternative valuations and redefining the costs of handling secondary materials, a better understanding of the establishment of a secondary market can emerge.

2. Problem statement

Based on the problem analysis, the construction of roads is one of the main consumers of raw materials. Thus, this type of construction is the focus of the thesis. Another focal point is incentivizing actors involved in construction through which a market for secondary raw materials could evolve. The ideal scenario, from this thesis' point of view, is for road construction to reuse and recycle more raw materials and/or substitute raw materials with by-products or alternative materials, as to prolong the depletion of virgin raw materials. As the primary actor in construction of roads in Denmark is The Road Directorate, this public developer is the focus.

The Danish Road Directorate has, through procurement and by being the largest road developer in Denmark, influence on how road projects are constructed and the degree of virgin raw material consumption. The Road Directorate can play a large role in creating and supporting a market for secondary raw materials. The extent of their role and how they practically can play an important role be yet unknown, and therefore it is found relevant to investigate:

How can The Danish Road Directorate facilitate the creation and the support of a market for secondary raw materials?

The *creation* of a market for secondary raw materials refers to initiatives that can kick-start and accelerate the development of such a marketspace. While the *support* of a market for secondary raw materials refers to changes in paradigms, policy instruments and practices that have an underlying long-lasting effect once the market is kick-started. Thus, an investigation of incentives outside of The Danish Road Directorate's field of action, is found equally important.

The following sub questions support the investigation of the problem statement in their respective chapters:

1. Chapter 8 answers: Which incentives, supporting a secondary market for secondary raw materials, are widely used in Europe?

2. Chapter 9 answers: What is the effectiveness of the highlighted incentives, based on evaluating the experience of European countries in this field?

3. Chapter 10 answers: What are Danish perspectives on adopting incentives from European countries?

4. Chapter 11 discusses: What important elements should be considered when establishing a market for secondary raw materials in Denmark?

3. Delimitation

Figure 6 illustrates the delimitations to this thesis. The delimitations are divided into primary and secondary areas of focus. This is due to the systemic framework of the thesis which cannot avoid referring to outside influences. In an attempt to refrain from involving all aspects of the complexity of networks, the orange secondary areas of focus are only briefly referred to instead of uncovering them fully. The delimitation in Figure 6 takes point of departure in the circular and linear journey of raw materials. The thesis thus covers essential points of interest from extraction to waste or circularity. Points of interest are here defined as areas where the circular economy of raw materials can meet barriers and where opportunities to incentivize utilization of secondary raw materials can arise. The aim of creating a market for secondary raw materials requires action from developers, such as the Road Directorate, government, and market actors. The framework for the thesis will thus be the four aforementioned areas of attention. A final delimitation is from the social aspect of the Brundtland reports' definition of sustainability (Verdensmaalene.dk, 2023). The focus is environmental and economic sustainability, but there are mentions of the importance of social sustainability as well. Additional delimitations are found and defined in the Glossary of terms.

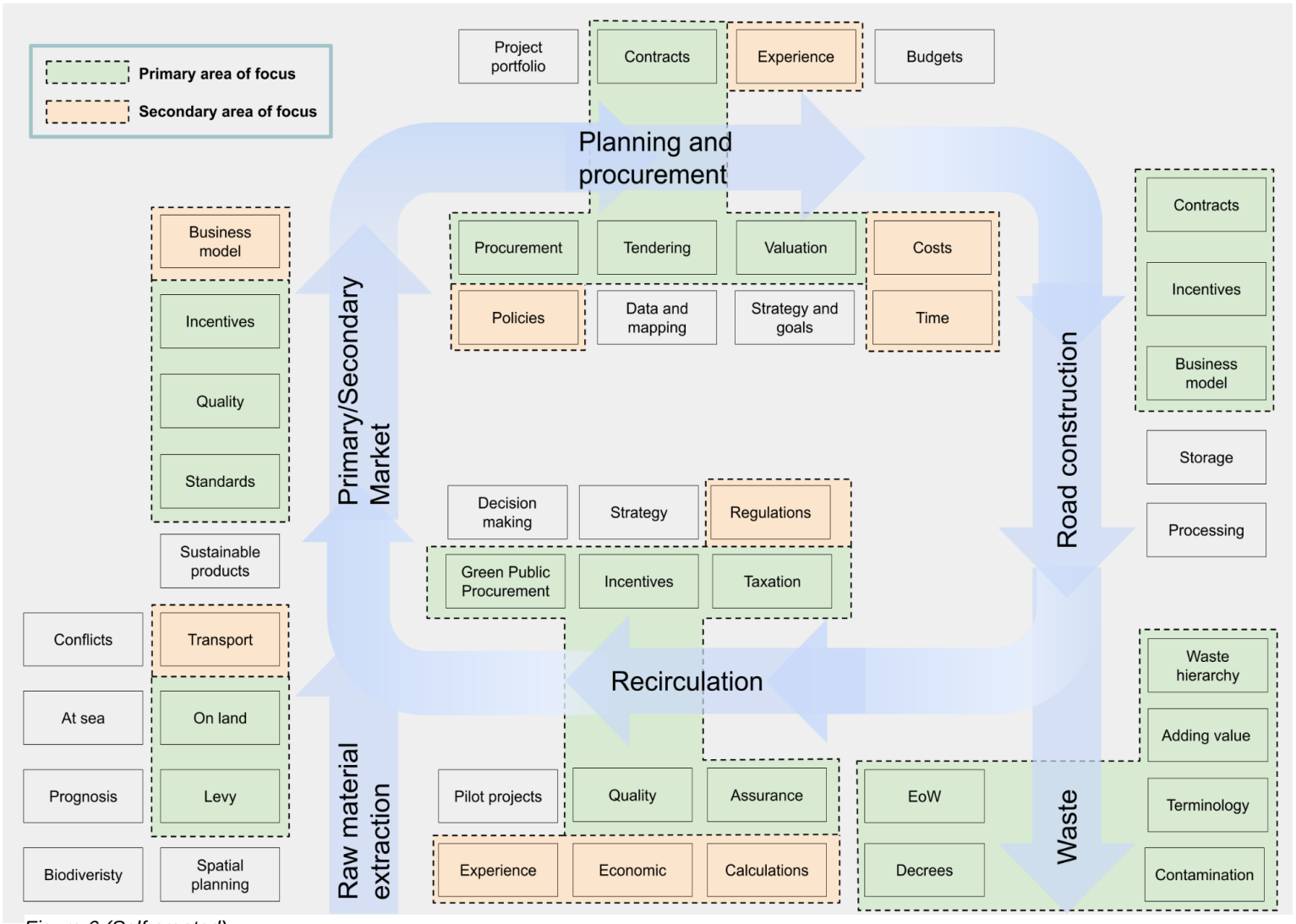


Figure 6 (Self-created)

4. Research design and reading guide

The aim of this thesis is to identify specific procurement tools that The Danish Road Directorate can use to decelerate raw material depletion and incentivize better reuse, recycling, and substitution of raw materials, as well as identify government-level incentives that can support this goal. The framework of the analyses and discussion is based on the four identified areas of attention: *procurement*, *policies*, *risk,* and *valuation*.

The first analysis identifies various forms of incentives through procurement used in Denmark, as well as other countries. The analysis also highlights government-level incentives through legislations and executive orders.

The second analysis uses EU CDW data to identify European countries that handle large quantities of raw materials combined with having good recovery rates. The aim of the data analysis is to find the countries that are the best at utilizing secondary raw materials. Thus, the incentives in these countries must be effectful. By identifying their practices and comparing them to Danish practices, it can be deduced which missing, but effective practices or incentives Denmark should adopt.

The third analysis looks deeper into the best performing countries' practices and incentives and compares them to the Danish Road Directorate's tendering practices. The aim of the analysis is to gain a better understanding of how the Road Directorate can implement learnings or tools that other countries have found effective in tendering road construction projects.

The discussion investigates the last two areas of attention: risk and *valuation*. Here these topics are placed within the framework of multi-level perspective and, specifically to *valuation*, the frame of discussion is ecological economics and the degrowth mindset. Following the analyses and discussion sums up the important focal points. They partly focus on what road developers, from the perspective of the Road Directorate, can do to transition their procurement practices to allow for better reuse, recycling, and substitution of raw materials. The other part, which focuses on what lies out of the Road Directorates possibilities for action, takes point of departure in policies and the multi-level framework. Finally, a visualization of different reduction pathways is presented.

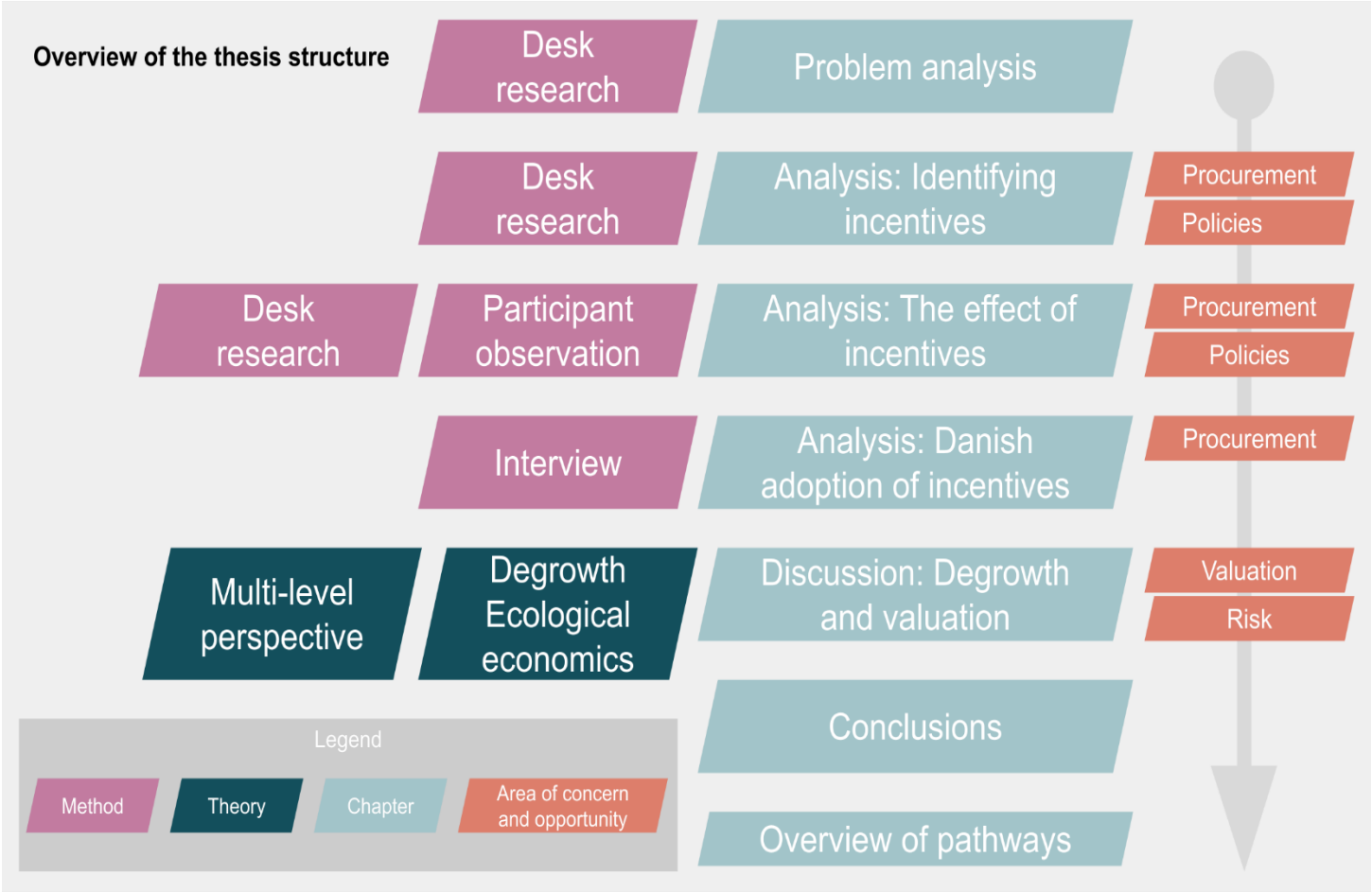


Figure 7 (Self-created)

5. Theories

5.1. Theory of science - Pragmatism

This thesis utilizes the ontology of pragmatism to perform research. Pragmatism is characterized by the sentence '*knowing the world as inseparable from agency within it*' (Legg & Hookway, 2021), which can be interpreted as, good research interacts with the world to understand the world. Pragmatism states that one can never truly understand the subject matter if the researcher is not engulfed by the subject matter. This means that hypotheses should be tested scientifically in the world of the subject matter. Pragmatism is the chosen theory of science due to this statement - and is why the thesis draws on interviews and participant observation from the subject matter world. The thesis also takes point of departure in the Danish Road Directorate and only refers to real tested methods. This also ties into another statement from pragmatism, which is '*a claim is only true if, and only if it is useful*' (Legg & Hookway, 2021). The thesis, its theory and claims should contribute to social progress in order to be useful in the ontology of pragmatism. Researching how a potential market for secondary raw materials could be established to combat raw material depletion and the negative environmental impacts accompanied by the extraction is regarded as useful to societal progression.

The truth that the thesis seeks to find, through its claims, is the knowing of the answer to the problem statement:

How can The Danish Road Directorate facilitate the creation and the support of a market for secondary raw materials?

The problem statement is sought to be narrowed by limiting the subject matter to the Danish Road Directorate, however, as another statement from pragmatism says '*articulate language rests on a deep bed of shared human practices that can never be fully made explicit*' (Legg & Hookway, 2021). This is interpreted as; one can never fully make the subject matter explicit due to multiple layers it lays on. This means that the knowing of the answer to the problem statement can never be truly understood. However, by approaching the problem statement from different angles, as the four areas of attention seek to, then a better understanding on the subject matter can be achieved. This multi-angle approach is attempted through the multi-level perspective.

5.2. Transition theory - The multi-level perspective

As this thesis researches the establishment of a new market in a construction sector in which the market is rigid, based on many years of developed practices, slow evolving, has small margins and is characterized by risk-aversion, the multitude of influences can easily increase the complexity and disperse the focus. Transition theory seeks to grasp the complexity of, especially sustainability transitions, and provides a framework for analyzing the many factors and actors that influence change or preservation. (European Environmental Agency, 2019). To research transitions, a system in which the transition must or does occur is to be presented. There are three main systems, in which human interaction happens (See Figure 8).

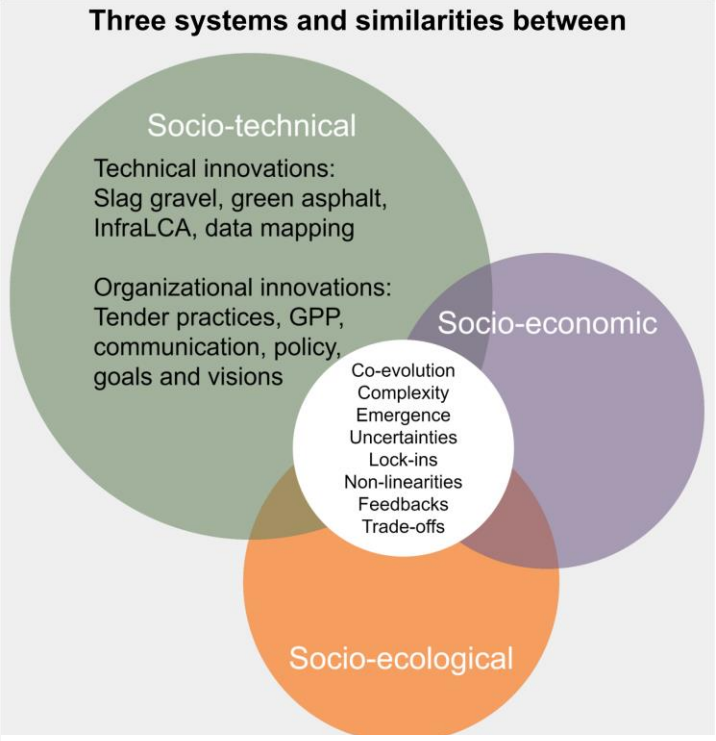


Figure 8 Reinterpreted based on (European Environmental Agency, 2019)

This thesis' perspective is the socio-technical system, in which interactions and relations are geared towards technical innovations and organizational innovations (See Figure 8). These innovations are seen as possible drivers for systemic change in the socio-technical sphere.

5.2.1. Systemic change in the socio-technical system

In this thesis, the aim is to create change in the socio-technical system to prevent the path-dependencies that the construction sector has created for itself. Rapid raw material depletion is avoidable through systemic change towards circular business models that promote better utilization of secondary raw materials in the construction sector.

As mentioned earlier, the construction sector is complex, due to interaction between several actors in the value chain that rely on each other to fulfill their usual roles. Their doings are influenced by the interactions between physical materials, social (jobs, practices, stakeholders, human factors etc.) and institutional (legislative, policies, etc.) elements (European Environmental Agency, 2019). The complexity of these interactions also adds to the construction sectors' rigidity, as these elements have co-evolved for many years (Geels, 2004).

Transition theory states that only applying pressure on one element, to try to induce change, has little to no effect, due to the tight connections to the other elements. These tight connections encompass business models that benefit the business as usual. The rigidity grows stronger as the involved actors seek to optimize and maximize the benefits of business as usual. Inducing systemic change takes equally complex measures, as it requires members of the construction sector to see benefits in the change, which in this case is circular business models rather than linear business models. Often it requires a large group of actors to see the circular business models benefits simultaneously. Additionally, it can also require some form of intervention or 'coincidence' that reduces the benefits of linear business models. Incumbent actors will only abandon a business model once they doubt its long-term viability. (European Environmental Agency, 2019)

5.2.2. Systemic change in the multi-level perspective

The Multi-level perspective (MLP) creates a more detailed overview of the phases of systemic transitions. MLP is characterized by the three levels, niche innovations level, regime level and landscape level and the interactions between the levels that induce change (See Figure 9)

The niche innovations level is where the technical and organizational innovations emerge, diffuse and gain traction towards disruption (European Environmental Agency, 2019). The niche innovations that are referred to in this thesis are any form of innovations that promote reuse, recycling, or substitution.

The regime level refers to where the complexities of interactions between incumbent actors occur. The incumbent regime refers to the structures that uphold whatever business models and interactions make up the business as usual. It can be stable, during business as usual, unstable during doubts and uncertainty, and disrupted and reconfigured due to niche innovations and circumstances that benefit alternative business models. (European Environmental Agency, 2019)

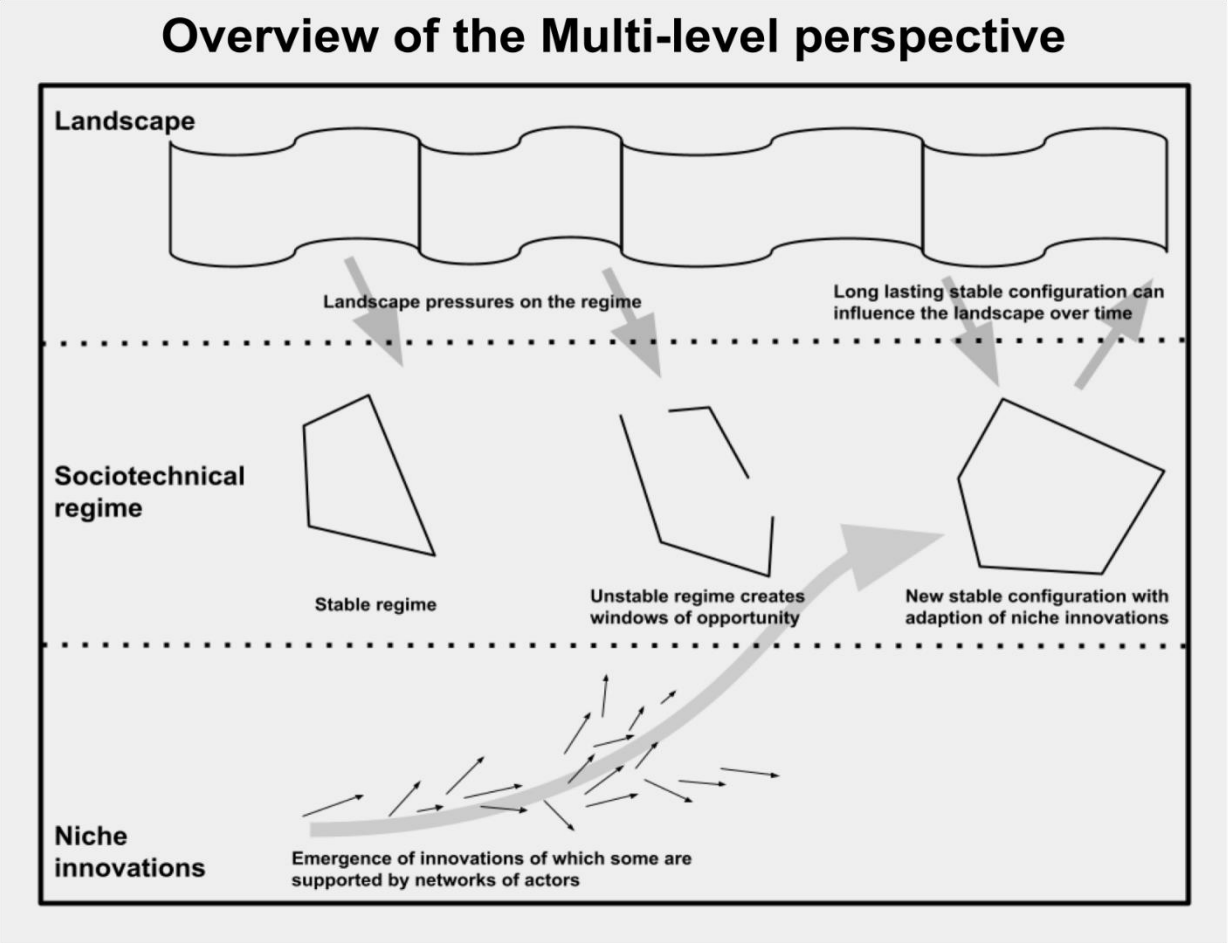


Figure 9 Self-created figure based on (Geels, 2004)

The landscape level refers to macro trends that are subtle and happen over long periods of time, often due to the actions of the incumbent regime. These landscape pressures can exert pressure onto the regime making it unstable and creating a 'window of opportunity' for niche innovations to disrupt. (European Environmental Agency, 2019)

The purpose of using MLP is to highlight the complexity of the problem statement and to apply the Road Directorates' actions into a larger system. As the Road Directorate is part of the incumbent regime, this level is the primary focal point. The landscape level is in this context seen as an enabler of an unstable regime, where the Road Directorate has an opportunity or need to transition, as the whole system changes. The niche innovation level is seen as a provider of tools and instruments of technical and non-technical nature that the Road Directorate can utilize in their part of the systemic transition.

5.3. Ecological economics and de-growth perspective

The ecological economics and the de-growth perspective are not, in this thesis, used as theories, but rather ontologies that support the framework of the thesis. They are alternative perspectives on classical economic understanding and provide an interesting counterpart when discussing the topic valuation, which permeates the thesis.

Ecological economics refers to the understanding of economics as bio-physical, meaning that economic and social processes should also be discussed in ecological terms (Røpke, Urhammer, Georg, & Jensen, 2017). In the thesis, this translates to discussing economics, for example cost benefits analysis', with a broadened view, including social and environmental impacts into expenses and earnings.

Fundamental understandings in ecological economics include:

- Growth limitations - Viewing the earth as a closed system in which social economics are participants.
- Technological limitations - Refusing to rely on technological improvements to solve environmental impacts.
- Distribution and futures - Ensuring equal distribution of limit resources in ways that are considerate to future generations.

(Røpke, Urhammer, Georg, & Jensen, 2017)

Especially the understanding of growth limitations ties in with the de-growth perspective, which takes a stand against the incumbent political landscape that pushes the agenda of growth. The de-growth perspective seeks to hinder growth, in this case, heavily reduce the virgin raw material consumption. (Røpke, Urhammer, Georg, & Jensen, 2017) This is an interesting perspective to refer to in the context of this thesis, due to its radicality and its complete opposition to the construction sector which is driven by development and growth.

6. Methods

6.1. Desk research

Gathering a state of the art, information on the Road Directorates practices, the procurement, and policies in Europe, etc. stems from desk research. The method encompasses acquiring knowledge from journals, reports, documents, websites, descriptions, studies, etc. (Bassot, 2022) Desk research provides all the knowledge, which is public, which for public developers is most material.

The desk research method is found to be a solid method for creating a state of the art and for gathering statistics, examples, and facts for further investigation. Additionally, it is also a good foundation for researching and gaining a deeper understanding and application of the theories used in the thesis. Desk research also supports and is reversibly supported by other methods, such as interviews and participant observation.

6.2. Semi structured interview

A semi structured interview is the interview form between structured and unstructured interviews. It utilizes the middle ground of being structured with preset questions, but also

allowing for unstructured tangents to occur when relevant or when they lead to answers of later intended questions. (Adams, 2015)

This interview form is selected due to the expert knowledge of the interviewees and the purpose of the interview being uncovering a deeper knowledge, rather than to compare answers with other interviewees. On the contrary, the author has acquired knowledge on the topic in advance and only wishes specific points to be elaborated upon, thus the relevant tangents and additional knowledge is less needed. Additionally, the unstructured nature of the other method used, participant observation, the semi structured interview made for easier processing of data.

A semi structured interview is conducted with George Thurley from the Dutch Foundation for Climate Friendly Procurement and Business. His expert knowledge on Dutch procurement practices and specifically the Dutch CO2 performance ladder facilitated a deeper investigation of differences between Dutch and Danish procurement practices.

6.3. Participant observation

This method facilitates broad and unstructured data collection, as the observer is an onlooker in workshops, group discussions, meetings etc. and only participates when needed. This method can produce messy data affected by personal views mixed with organizational views.
Interview given the unstructured nature of the method combined with the anonymous role of the observer (n.d., 2023). However, it is found that this unstructured data can be used to uncover otherwise hidden details and highlight the human factors that are often shielded by interviewees representing an organization's views. Participant observation is in this thesis used due to its enabling of finding data that can often be difficult to find in organizations.

The activities in which participant observation was performed was in the work setting of Center for Offentlig-Privat Innovation which facilitates innovation processes with public developers. The data collection is acquired through summaries and notes. If used for citations it is with the consent of the person quoted.

7. Road construction in Denmark

This section serves as a clarification of the actors involved in road construction, the process of constructing roads including material consumption, practices and initiatives that are used today, as well as potentials for circularity.

7.1. Public road development

In Denmark there are mainly two public developers that construct roads, either The Danish Road Directorate or the municipalities. Other developers may construct smaller roads, but this is not regarded as their main area of construction.

The Road Directorate is an administration under the ministry of transport. It is responsible for the government roads, which include motorways, slower motorways (motortrafikvej), many country roads and bridges. In total they are responsible for approximately 3.800 kilometers of road. As with many of public developers the construction of the roads is tendered and constructed by private contractors. (Vejdirektoratet, 2023) Figure 10 below shows the large project to be tendered in the year 2023 and 2024.

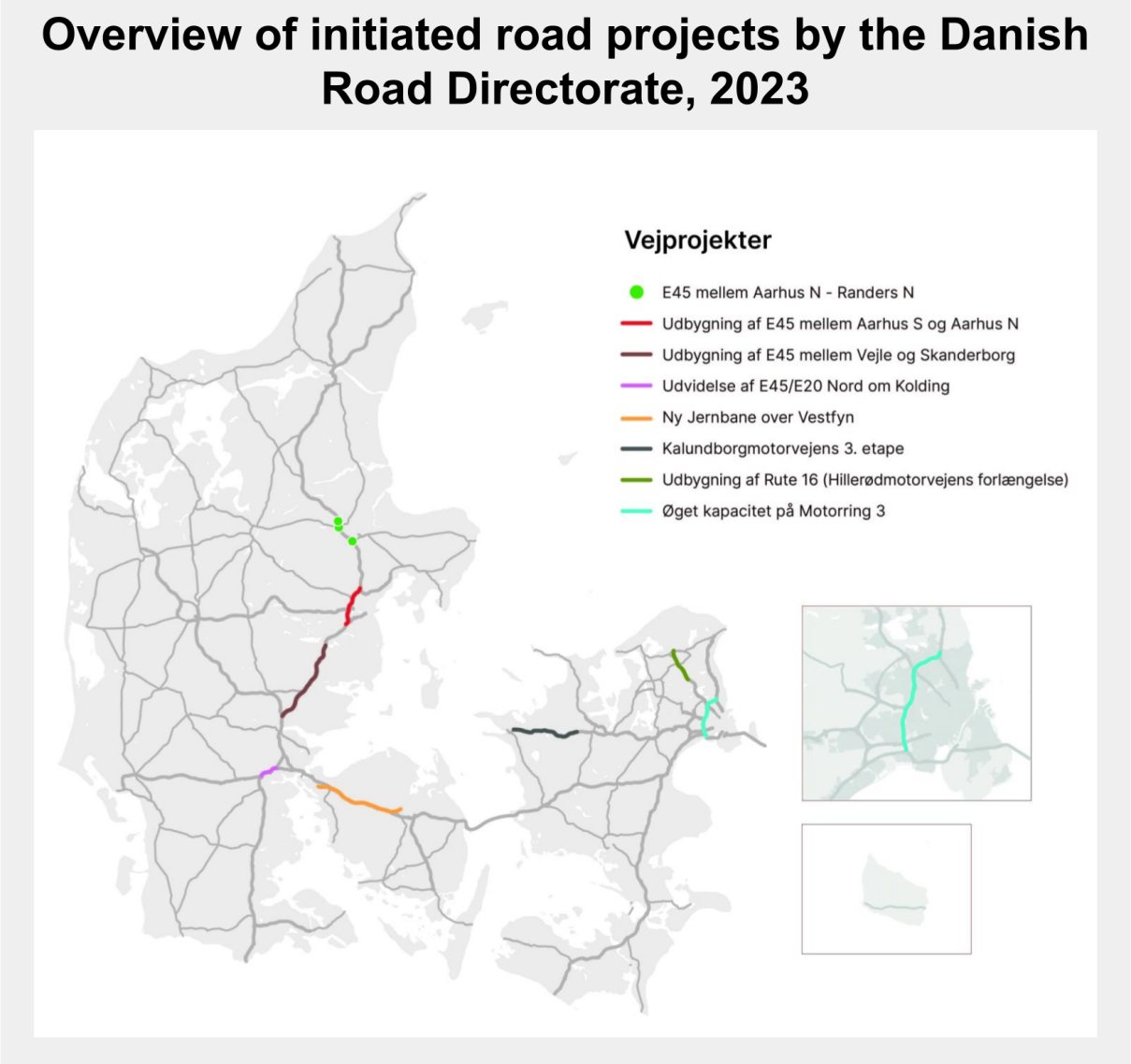


Figure 10 (Vejdirektoratet, 2023)

7.2. Constructing a road

When constructing a road there are multiple phases, of which many are not the focus of this thesis. The phases include measurements, geographical inspections, expropriations and compensations. The main area of focus is the construction of the road. The translated graphic on the right shows the construction process with the raw materials used for each phase (Figure 11).

7.3. Existing circular practices

The Danish Road Directorate is currently experimenting with bitumen stabilized material (BSM), for the base layer. This material mainly reuses stone, gravel, and bitumen. More knowledge is being gathered on the material. (Vejdirektoratet, 2023)

The Road Directorate has for some time sought to create soil balance in their projects to minimize soil management. This means reusing excavated soil in one area of the project as filling for another area. (Vejdirektoratet, 2023)

Several public developers, including the Road Directorate, have experience in using lime as a stabilizing material where possible. This method reduces the need for excavating and establishing the stabilizing gravel layer. (SR-Gruppen, 2023)

Lastly, some municipalities have experience in using slag gravel, which is an industrial by-product, in the base layer as a replacement for virgin stone and gravel. (Afatek, 2023)

The best areas for potential circularity based on what is possible with current technology is when constructing the bottom protection, the stabilizing layer, and the base layer (See Figure 11). Currently whenever sand and gravel are used in these areas, they can likely be substituted with secondary raw materials from outside the construction site.

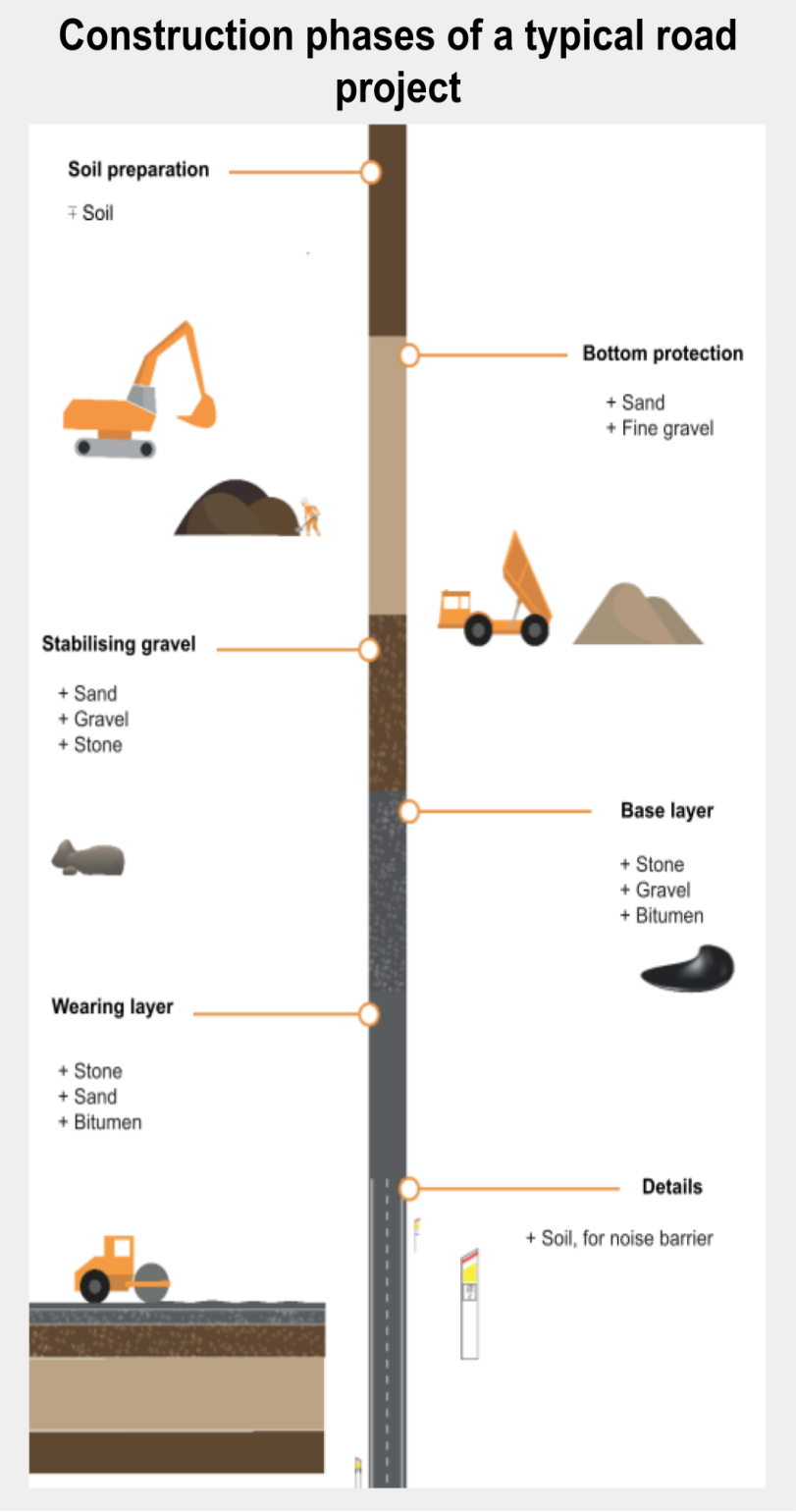


Figure 11 Reinterpreted and added to, based on (Vejdirektoratet, 2023)

7.4. The Danish Road Directorate as influencers of the market

Most roads are completed in the traditional way shown in Figure 11, despite municipalities and the road directorate having experience in utilizing alternative circular solutions. Even though the knowledge base is being widened, there are still barriers to what can be implemented as standardized methods on a systemic level.

The Road Directorate has options for actions within their own procurement and tendering, however, other essential areas of attention must act in unison (See Figure 12).

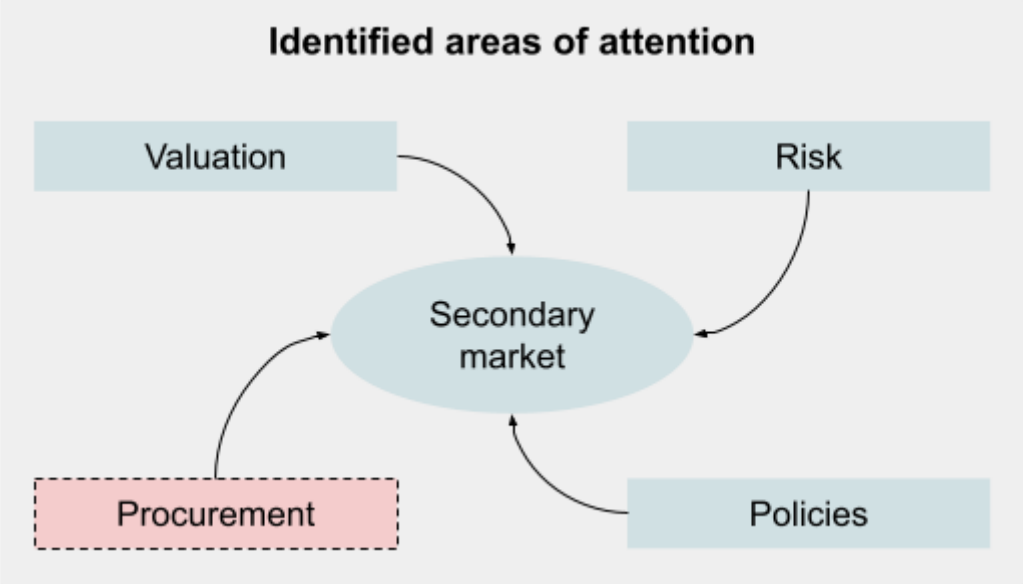


Figure 12 (Self-created)

These options for actions within their organization are investigated in the following chapter, before uncovering examples of inducing change through incentives on a government level.

8. Incentives as leverage for supporting a market for secondary raw materials

This chapter reviews the incentives of countries that are comparable to Denmark with the purpose of highlighting initiatives that can have a positive effect on recirculation of raw materials and decelerate the raw material depletion. This chapter answers the sub question:

Which incentives, that support a secondary market, are widely used on a global scale?

The chapter initially distinguishes between incentives that procurers use in their tenders and incentives through policies governed by the state. They are both found equally relevant but are separated in this section.

8.1. Incentives through procurement

Procurement is where the public developers have the biggest opportunity to influence their projects. In their tenders different qualification methods, tools for evaluation, criteria etc. can be utilized to promote bidders with a more sustainable approach to projects. There are several details that can be tweaked during procurement and this section seeks to highlight the most common and important ways of incentivizing circular road construction.

8.1.1. EU Green Public Procurement - Award criteria and requirements

Green Public Procurement (GPP) is a voluntary instrument that public authorities can use to assure bidders with solutions with smaller environmental impacts as well as to stimulate sustainable market innovation. The GPP instrument consists of several items such as policy frameworks, an advisory group, national actions plan and most relevant to this thesis GPP criteria. In the GPP criteria database, specific criteria for road construction and maintenance can be found. These are regularly updated to reflect the most recent market developments. (EU, 2023)

There are criteria both for pre-selection and specific requirements that the bidder must either describe how to meet or submit documentation for. These criteria can be utilized by purchasers either as inspiration or directly in their own tenders. The percentages can be edited depending on the project in the following example:

"The contracting authority shall award points to tenderers that achieve greater than or equal to 15% by weight of the recycled content, re-used content and/or by-products for the sum of the main road elements in Table (c)." (EU, 2023)

Utilizing weight in the award criteria is also a valuable tool to show the bidder what areas are important to the project. Traditionally, price will often weigh the most, but it is possible to weigh environment, quality, and mission understanding more than the usual 10-30 pct.

Several European countries, Sweden, Italy, Belgium have experience in using GPP, with the country with most examples being the Netherlands.

There are also other green procurement requirements that are widely used in construction but are used less in civil engineering works. This distinction is important, as requirements for sustainability ratings and some life cycle tools are not developed for these types of civil engineering works.

Denmark vaguely uses GPP regarding construction. There is a national strategy for green procurement, in which it is acknowledged that construction procurement is the government's largest emitter. However, the strategy only refers to the National Strategy for Sustainable Construction, which does not account for roads. (Finansministeriet, 2020) The Danish ministry of environment shares links on their website for different forums, task forces and EU criteria

that can be copied into tenders but provide no concrete GPP-related content towards road construction. The agency for competition and consumer protection provides a solid guide toward green procurement and does have several mentions of construction and other key words such as eco-labels, award criteria and circular letters to pay attention to, but no mentions of roads either (Konkurrence- og Forbrugerstyrelsen, 2022). This is not specific enough to provide value for the Road Directorate.

Other important instruments encompassed or inspired by GPP are highlighted below.

8.1.2. LCC and LCA tools

Life cycle costing (LCC) and life cycle assessment (LCA) are both tools that allow procurers to visualize cost and environmental impacts from the product stage, the construction stage, the use stage and the end-of-life stage or life-cycle stage. These tools nuance the costs and impacts of a procured product, as it allows information about the past, present and future of the contents of the contract. These are tools that are valuable for developers to make informed decisions during the procurement.

The EU procurement rules state that a contract must be awarded based on the most economically advantageous tender (MEAT). This approach seeks to also consider elements that are beyond lowest price, such as environmental impacts. This is also adopted into the Danish law on offers (Tilbudsloven). LCC is a tool that can aid in this assessment. When using LCC to find the MEAT, the price or cost encompasses the purchasing prices (delivery, installation, insurance etc.), operating costs (energy usage, water usage, maintenance) and end-of-life costs (disposal, sale, etc.). (EU, 2023) If a country charges for CO2-emissions or other environmental impacts, then they are also to be included. By using LCC, developers can assess the MEAT as well as identify hotspots. This, however, requires that the tender sets requirements for contractors to either complete their own LCC or provide documentation and data that can be used in an LCC tool.

When determining the environmental impact in non-economic ways LCA is to be used. This can be used in conjunction with other performance-based tools, such as the CO2 performance ladder, to determine which bid has the lowest CO2-emission rates for example. An LCA is used to determine the sustainable value of a project and can be used to create an environmental cost indicator (ECI). This is another method for valuation of sustainability and transforming sustainability into economics. LCC can be built upon LCA results.

The following Table 3 summarizes selected countries' use of LCA:

Adoption and use of life cycle tools

Country	Adoption
France	Contracting authority can require that specific environmental criteria are fulfilled via LCA
Italy	Environmental criteria are mandatory and to be filled out through LCA-based tools
The Netherlands	Authorities have developed DuboCalc which bidders can use in tenders. Used ECI to compare environmental performance on different designs. This promotes healthy environmental competition among bidders to change and adapt their projects. DuboCalc results are also used to deduct price in bids
Denmark	Less strong links to LCA in tenders, but the knowledge base is big, partly due to previous voluntary sustainability ratings using LCC and LCA which are now mandatory (for buildings). The Danish Road Directorate has also created their own modules, VejLCA and InfraLCA

Table 3 Based on data from (OECD, 2016) and (European Commission, 2021)

8.1.3. Performance-based tools - CO2 performance ladder

The CO2 performance ladder is a European GPP instrument that has primarily been rolled out in the Netherlands. It was developed in the Netherlands in 2009 by public developers and has evolved into a standardized procurement tool (Appendix 1). The purpose of the instrument is to use award criteria to influence reduced CO2-emissions from bidding companies. Each bidding company entered in the scheme, gets a certification reflecting their level (1-5) on the performance ladder. Their level is based on their initiatives in reducing CO2-emissions from scope 1, 2, 3, through investments in sustainable innovation, knowledge sharing etc. but also measures to reduce the emissions from the tendered project. The more effective a company is at reducing CO2-emissions, the higher level they are placed on the ladder. This gives them an advantage when bidding on public projects. When bidding on a project, the company sets an ambition level on the tendered project which, if they win the tender, will be set as a performance requirement. Each step up the ladder results in a percentage fictitious discount on the entry price (See Table 4). (OECD, 2023) There are no set percentages due to context, but SKAO, the developers of the CO2 performance ladder, provide guidance for contracting authorities on this (Appendix 1). Thus, this is a method for procurers to valuate sustainability in the award phase, which is important in terms of the principle of MEAT.

Example of three bids in CO2 performance ladder award system

Company	Entry price	Level on the CO2 ladder	Fictitious discount	Fictitious price	Awarded the contract
A	9,7 mio. EUR	None	0%	Valuation	No
B	10 mio. EUR	3	4%	9,6 mio. EUR	No
C	10,3 mio. EUR	4	7%	9,58 mio. EUR	Yes: 10,3 mio EUR

Table 4 (SKAO, 2021)

An example, also from the Netherlands, is a public contract on widening a 13-kilometer stretch of road. The Rijkswaterstaat was the developer and executed the tender, which was based on finding the best combination of price and quality. For this, the CO2 performance ladder and the aforementioned DuboCalc were used. The winning bid had the highest level on the CO2 performance ladder and was therefore given the highest award advantage. (European Commission, 2018) Table 5 below shows different percentages from different Dutch and Belgian developers and contracting authorities (Appendix 1).

Different usage of ambition levels in procurement

CO2 ambition Level	Fictitious discount on tender price used by Rijkswaterstaat	Fictitious discount on tender price used by ProRail	Fictitious discount on tender price used by the Flemish Road and Traffic Authority, Belgium
0	0%	0%	0%
1	1%	1%	2%
2	2%	2%	4%
3	3%	4%	6%
4	4%	7%	6%
5	5%	10%	6%

Table 5 Forwarded by interview respondent, see Appendix 1.

The Netherlands have had this procurement tool for 15 years, and the market has adapted to it, so that it is no longer a major deciding factor in who wins the tender, however, in developing markets it can be a deciding factor and help raise the environmental bar of the market (Appendix 1)

Another example of performance-based award criteria is a new Danish tender for road construction by The Road Directorate. This tender aims at reducing CO2-emissions from road

construction through zero emissions machinery. In the documents, bidders are awarded a fictional discount or surcharge to the entry price, in short, based on the share of zero emission machinery included in their proposed fleet. (Vejdirektoratet, Bestemmelser om udbud og tilbud, 2020) This has not yet been tried regarding reuse, recycling, or prevention, but would essentially work the same.

8.1.4. Bonuses and penalties

Specifying bonus and/or penalty schemes in the tender is beneficial to encourage higher ambitions that were initially entered in the bid or discourage the opportunism and changes to project execution. An example of a bonus could be, that the tender states:

For every additional percentage of recycled gravel used in x construction phase in relation to the initial contract, the contractor will be awarded x DKK.

This is also an example gathered from zero emissions machinery tender from The Danish Road Directorate but edited to be relevant to raw materials. This would hopefully raise the ambitions of the contractor to use more than the initially agreed amount of recycled gravel, depending on the bonus being attractive compared to possible additional costs.
An example of a penalty could be, that the tender states:

For every percentage of recycled gravel under the agreed upon amount, the contractor will be invoiced x DKK.

This would hopefully discourage the contractor from reverting to easier, possibly cheaper, traditional construction practices.

Penalties are used more often than bonuses, as bonuses require a larger budget from the developer. There are also instances of contractors wanting to maximize the potential bonus by undercutting the initial amounts, knowing that they can deliver more recycled gravel for example, when the project starts. (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2020) This of course puts the contractor at risk of not winning the bid, if ‘environment’ is weighted high in the award criteria.

An example of this is the Finnish Transport Agency that used bonuses on several factors in their tender for a road project. The tender promoted the use of ash, a by-product, in the construction of the road, stating that each ton of ash used released 3 EUR and maximum 100.000 EUR. (Cleantech Hankinta Mappi, 2014)

Another example of bonuses is the Swedish model, where a baseline for reduced CO2-emissions is calculated through a tool called Klimakalkyl. If the contractor further reduces CO2-emissions in any way, they will receive 1 pct. of the contract sum. (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2020)

The Dutch foundation for climate friendly procurement and business, also creators of the CO2 performance ladder, has published a guide on green procurement. The guide provides an example of applying the appropriate penalty, and it is as follows: The fictional CO2-reduction value (outlined in the CO2 performance ladder in the tender) minus the actual CO2-reduction value times a factor (e.g., 1,5). (SKAO, 2021)

8.1.5. Reporting and enforcement

Whilst criteria and requirements are useful, there must also be set a framework in the tender that allows the developer as well as the contractor to keep track of how well the contract agreements are met. These types of contracts often succumb to changes, due to the practical nature of construction. Delays, missing materials, weather, and other conditions are typical elements that can change the course of each construction phase. These changes tend to lead to opportunism, which often can be a breach of contract. (Kadefors, Lingegård, Uppenberg, Alkan-Olsson, & Balian, 2020) To counteract this, a tender can require weekly or monthly reporting from the contractor to follow-up on proceedings. Combining this with penalties is often good practice.

Most public organizations will benefit from the data that this reporting gathers. Data can be stored and used as baselines for other contracts, or to spot pitfalls and potentials. This can aid in creating tender paradigms that work across a developers' project portfolio and can counteract mishaps that can occur in creating tenders project by project. For example, the municipality of Copenhagen has created tender paradigms, based on experiences from earlier projects, that are available on their website. (Københavns Kommune, 2023)

8.1.6. Summary of incentives through procurement

To summarize, there are several initiatives of which have varying impacts (See Table 6). Some are widely used, and some are, as of yet, specific to one country. There are also many ways to execute and combine these incentives. The following section zooms out of the public organizations and investigates incentives from higher up in the public hierarchy.
As gathered from the review, Denmark utilizes all these tools in procurement, but in different ways and some not even in the construction sector. The Danish Road Directorate uses bonus

Table of selected incentives through procurement

Incentive	EU GPP	LCA and LCC	Performance based tools	Bonus and penalty	Reporting and enforcement
Measure	Broad term of use of 'green' procurement instruments and criteria	Life cycle tools to determine environmental impacts and costs	Award criteria to evaluate the most environmentally performing bid/bidder	Tender tool to ensure incentivize efforts above baseline and discourage efforts below baseline	Tender tool to minimize opportunism and diversion from the contract. Useful for data collection

Table 6 (Self-created)

and penalties, and reporting and enforcement regularly, although not always specifically on circularity. They have experimented with performance-based tools, but again only on zero emissions machinery. Lastly, they develop and use LCA heavily. This is where they are most advanced.

8.2. Incentives through policies

Although The Road Directorate has options for ensuring reduced virgin raw material consumption via their tenders, there are also equally large opportunities that require action outside of their organization. Incentives from the government can impact construction practices and can make changes to public procurement tenders seem easier, or less risky, for contractors to fulfill. (Khalfan, Noor, Maqsood, Alshanbri, & Sagoo, 2015) states in their research, when respondent were asked about government incentives, that:

"All respondents stated that they believed government incentive provided a good reason for them to invest in sustainable initiatives in partnership with their clients" (Khalfan, Noor, Maqsood, Alshanbri, & Sagoo, 2015)

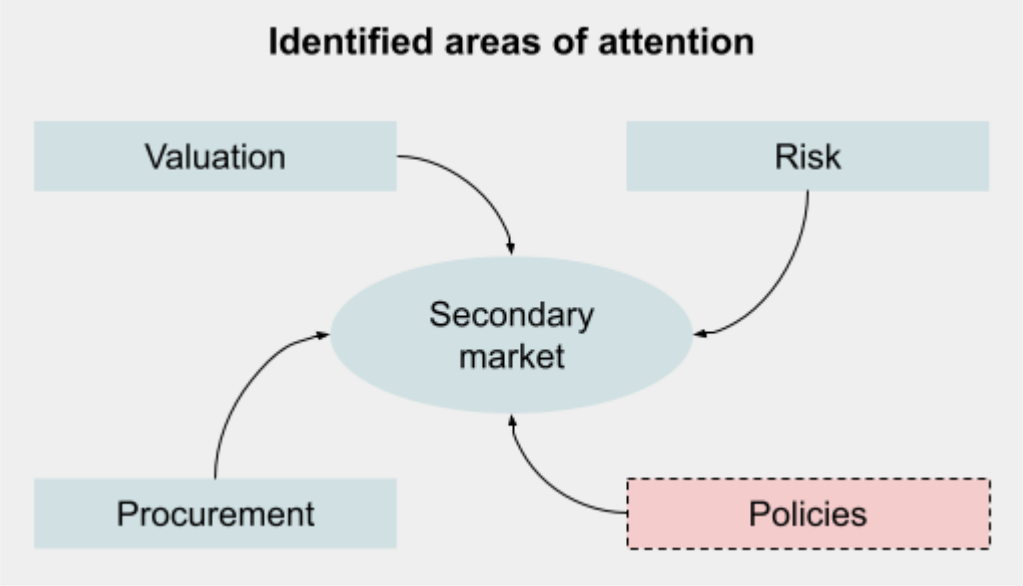


Figure 13 (Self-created)

While changing procurement practices seem to be able to support markets for secondary raw material utilization, to some degree, government incentives can have a kick-start effect that forces the market to adapt faster to GPP. This next section covers inducing change through incentive on a government level through regulations (See Figure 13).

(Saka, Olanipekun, & Omotayo, 2021) refer to three levels of creating incentives that support sustainable construction, by law, by executive orders and by reward and compensation.

8.2.1. Incentives by law

By law means that governments, through a legislative process create incentives through requirement and regulation (Saka, Olanipekun, & Omotayo, 2021). With this method, governments that work based on environmental goals will aim for a minimum environmental performance of construction and use legislative measures to pursue environmental goals. By law this seeks to lift the whole construction sector to meet certain criteria otherwise there will be repercussions in forms of punishments. This method, though effective in most cases, is not based on voluntarism, which often means that the incentive has less support (Ibid.). An example of this is the Danish 'National Strategy for Sustainable Construction' which, by necessity, only incrementally forces increasing environmental requirements onto the construction sector towards 2029. This strategy is created based on the Danish 2030 climate goal (Energistyrelsen, 2023) and utilizes slow incremental stages to minimize the disruption and possible resistance.

8.2.1.1. Examples of incentives by law

Levies and fees/charges are a common tool to incentivize alternative measures. Levies are monetary amounts that are paid, typically for products, and collected by a government or authority, and fees are charges that are either added or subtracted (rebate) from the original purchase. They have both been widely implemented globally in different sectors. Some of the most well-known examples are the 'tax breaks' on the purchase of electrical vehicles in Norway to discourage purchasing of combustion engines and the CO2-charges on fossil-based energy production across Europe, to promote renewables.

In Denmark there is a levy on raw materials at 5,56 DKK/ton. Earlier the levy was at 5,27 DKK/tonne before it was changed in 2023, of which the expected effect was increased recycling rates and less quarrying. The increase is marginal and has been a topic of discussion for some time. The interest organization for the Danish regions, who are raw material authorities, published a report in 2020 recommending an increase to 10 DKK/ton to have an impact on the depletion problem (Copenhagen Economics, 2017). Estimates are that the marginal increase in the Danish levy will have no impact. The first Danish levy of 1990 had initial effect, but the market adjusted over time and increased quarrying is still occurring (Aksig, 1992).

The UK also has a levy on raw materials, converted to Danish currency, at approximately 34 DKK/tonne. Previously this was approximately 30 DKK/tonne before 2008 until it was increased twice in 2008 and 2009. The expected effect of its introduction was to incentivize use of recycled and by-product materials over virgin raw materials (Gov.dk, 2023). As Figure 14 shows, there has been an increase in recycled raw materials, however the overall extraction has been increasing since the levy in 2009.

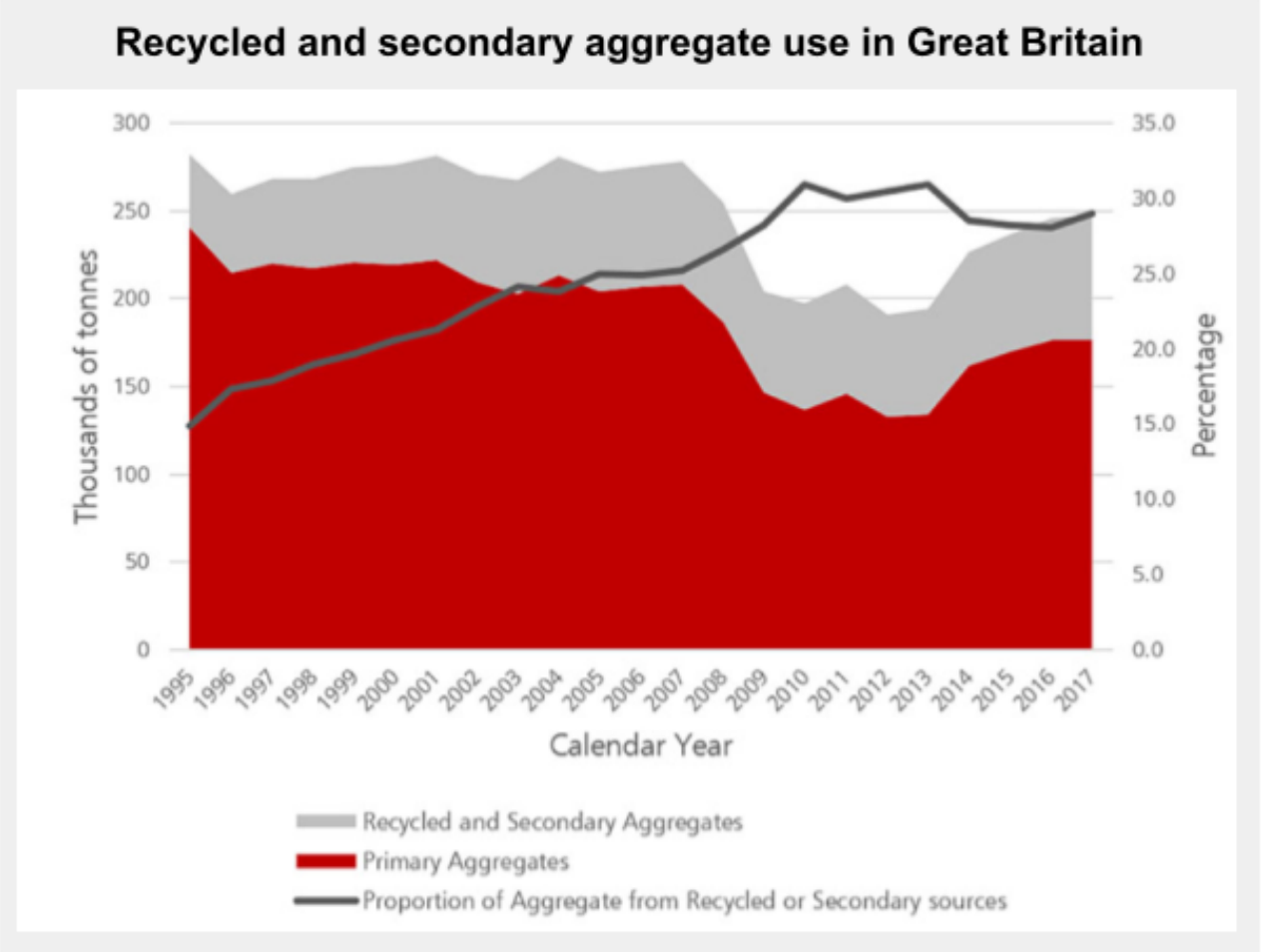


Figure 14 (Gov.uk, 2023)

In this case, the levy has been effective in promoting recycling and secondary utilization, but not in preventing or lowering extraction. The drop off in 2007 in Figure 14 is most likely due to the financial crisis and not debates on increasing the levy.

However, in a recent 2020 evaluation of the UK levy, the report states that the levy amount has reached its effectiveness, and that the jurisdiction now focuses on narrowing exemptions. As of now, there are plenty of public civil engineering works that can apply for exemption as well as companies that export (HM Treasury, 2020).

8.2.2. Incentives by executive order

An executive order is a slightly less permanent form of regulation, as it can be changed or rescinded by the relevant jurisdiction. Some executive orders are enforced in different ways depending on the authority or municipality. This is for instance the case in developers' application process for permits regarding re-incorporation of soil in digging projects (NIRAS, 2017). Executive orders often function as drivers for new goals and programs, but with a lack of regard for effective implementation (Saka, Olanipekun, & Omotayo, 2021). They are however, created faster than law and can have quirks that make them usable in for instance re-incorporation of soil, depending on how they are interpreted by developers and authorities.

8.2.2.1. Examples of incentives by executive order

In Denmark a well-known executive order that aids in reuse, recycling or utilization of by-products is the residual product executive order (Restproduktbekendtgørelsen). This encompasses rules on utilizing by-products, soil and sorted C&DW, with the goal of reducing the amount of waste for landfill or incineration. This executive order permits the usage of residual products in selected projects. (Retsinformation, 2016) With this executive order, selected by-products are vouched for, and thus makes utilization of them less risky.

8.2.3. Incentives by reward and compensation

Incentives by law and by executive order are similar due to their compulsive nature. In some cases, this is the most effective way of enforcing transition, especially in rigid industries. However, in other cases, preceding voluntary incentives can be a better and easier approach. This is the reward and compensation approach, in which beneficiaries gain from taking a risk. Actors could either comply voluntarily and gain long term market advantages by being early adapters, or they can have expenses partially covered by government funds etc. (Saka, Olanipekun, & Omotayo, 2021)

8.2.3.1. Examples of incentives by reward and compensation

In Denmark an example of this would be the voluntary sustainability class, where developers and contractors engage in voluntary action to, among others, implement circular construction in a project. The incentive, before it was adapted into law, was the knowledge and competence building, knowing that the requirements will be mandatory in the future.

Reward and compensation do also link to several of the aforementioned methods of procurement, in which contractors are rewarded for exceeding baselines.

In Denmark a programme that supports development and demonstration projects (Miljøteknologisk Udviklings- og Demonstrationsprogram (MUDP)), gives grants and counseling to innovative projects that secure sustainable development. This is a government incentive to financially support or compensate for risk-taking in sustainable construction development. The grant pool for demonstration projects is 57 million DKK. (Miljøministeriet, 2023)

In terms of compensating for risk-taking, the Danish Landsbyggefonden provides a green bond scheme for energy efficiency renovations. This green bond seeks to guarantee energy savings. If the calculated savings are in fact not gained in practice, the green bond will cover the difference. In utilizing secondary raw materials, involved actors would be guaranteed by the bond, which mitigated the argument of risk. So far, there are no green bonds in Denmark regarding civil engineering works.

The innovation fund is another initiative mandated through executive order, which role it is to support and invest in sustainable and innovative solutions. The fund finances their investments through grant acts., and specifically environmental endeavors through their programme 'Innomissions' (Innovationsfonden, 2023). Entrepreneurs, knowledge institutions and actors such as The Road Directorate can apply for grants through the innovation fund, to finance additional costs accompanied by innovative procurement or for example public-private procurement (market dialogs, workshops, human resources, alternative materials etc.).

Table of selected economic measures through policies

Incentive	Description
Levies, fees, CO2-pricing ***Legislative incentive***	Instruments that make consumption and emissions more expensive and alternatives cheaper. Statutory order for law on raw materials Statutory order for law on carbon dioxide fee on certain energy products
Grants ***Voluntary incentive***	Cover additional expenses that are linked with emerging markets. Given by programmes and institutions. The Danish innovation funds' programme 'Innomission'
Green bonds ***Voluntary incentive***	Guarantee that covers difference in expected expenses and actual expenses Landsbyggefonden green bonds on energy efficiency initiatives and renovations

Table 7 (Self-created)

Table of other selected incentives through policies

Incentive	Description
Mandatory procurement tools ***Legislative incentive***	Voluntary schemes that are phased into law. Laws that make tools such as LCA mandatory Danish building code has mandatory LCA
Executive orders ***Legislative incentive***	Rules that in some cases can clarify proceedings and mitigate risk Statutory order on residual products
Sustainability schemes ***Voluntary incentive***	Voluntary schemes that have yet to be phased into law. Providing frameworks for benchmarking and testing The voluntary sustainability class

Table 8 (Self-created)

8.2.4 Summary of incentives through policies

To summarize, there are plenty of ways to create incentives from a government perspective. Of the selected forms of incentives (See Table 7 and Table 8), there are still multiple ways to execute them, and even more when combining them. Some are of legislative nature, and some are voluntary. As mentioned earlier, the legislative measures are used by the government to pursue environmental goals whereas voluntary measures work to develop the market and incentivize innovation without being too restricting and whilst securing a fair market. A good

balance between these measures ensures the principle of proportionality in the market (Udbudshuset, 2023).

The purpose of the analysis is, as with incentives through procurement, to create an overview of incentives and categorize them. The purpose of the following analysis is to identify the effects of the incentives, specifically regarding establishing markets for secondary raw materials.

9. Effectiveness of incentives

Investigating incentives from a public developer and government standpoint results in several incentives being highlighted. The aim of this chapter is to understand the effectiveness these incentives have, specifically on creating and subsequently supporting markets for secondary raw materials. Narrowing the incentives down to the essentials and finding the best combination is the secondary goal. Firstly, a state of the art on Danish performance in CDW management and raw material production is created. Good CDW management combined with handling and producing large quantities of raw materials may indicate that a country has effective incentives and policies in place to recycle and reuse secondary raw materials and/or decelerate virgin raw material depletion. The state of the art is used as a baseline for comparing the performance of other European countries.

9.1. State of the art on Danish performance producing raw materials and managing CDW

Raw material production in Denmark is relatively high compared to other countries and when considering the area of the country. Denmark is the sixth largest producer of raw materials (sand, stone, and gravel) in Europe per Tonnes per Capita (See Appendix 2). This is the reason behind the spatial conflicts in Denmark when creating raw material extraction plans. Denmark also imports more raw materials than it exports. It is unclear from data to find out the specific materials.

In terms of CDW generation per Tonnes per Capita, Denmark is barely above the average in Europe (see figure x). This means that Denmark, despite being one of the larger raw material producing countries, is fairly good at utilizing the raw materials instead of producing excess waste. This is visualized through figure x, that shows that Denmark is below average in landfilling. This does, however, not equate to high utilization value, as Denmark has a relatively high rate of incineration. This is the result of a ban on landfilling waste that is considered suitable for incineration (Deloitte, 2017).

Upon desk research it is found that Denmark has the following incentives and policies set in place, that are important to highlight regarding CDW management:

- Green Public Procurement
- Levy on primary raw materials

- Landfill fee (64 EUR per Tonnes)
- Estimates on future projections on CDW generation
- Legislation that promotes recycling of unpolluted, sorted, processed soil under The Environmental Protection Act (Retsinformation, 2019)
- Statutory Order on recycling of residual products and soil in construction work (Retsinformation, 2016)
- Circular on the use of crushed asphalt in road construction (Retsinformation, 1985)

Generally, Denmark is a good performing country in terms of recovery. According to (Deloitte, 2017) Denmark recovers 87 pct of treated CDW. However, in Denmark there is research suggesting that there are different interpretations of recovery, with some actors interpreting as reuse. Recovery in Denmark is a broad category that encompasses higher and lower utilization values (See Figure 2) (NIRAS, 2017). In conjunction with this it should also be mentioned that Denmark has no backfilling definition or End-of-Waste criteria either (Deloitte, 2017).

There are, however, other countries with higher recovery rates that also handle more raw materials than Denmark. These countries can provide insight into opportunities of better utilization of secondary raw materials in Denmark. In the following section other countries that produce or handle large quantities of raw material and simultaneously have good CDW management are identified.

9.2. Identifying European countries to learn from

The effectiveness of incentives is investigated by country. To understand what incentives are effective, data is pulled on raw material production, mineral CDW generation rates, recovery rates and landfilling rates to determine the leading European countries in these categories. It can be determined that the leading countries must have the most effective incentives that might be helpful to apply in a Danish context.

Raw material production gives insight into which European countries handle most materials. If countries that handle large quantities of material also have data that shows effective recovery and low landfilling rates, then these are the countries to learn from. Adjusting for export, it is deduced that the leading consumers as well as producers of raw materials in Europe are, Belgium, Germany, Luxembourg, the Netherlands, Finland, and Estonia. For further insight into the selection see Appendix 2.

Mineral CDW generation highlights which European countries generate the most mineral waste, largely from construction. As with raw material production, if countries produce large quantities of waste, but also show high recovery rates and low landfill rates, then these are countries to learn from. Comparing the CDW generation per Tonnes per Capita shows that Malta, Belgium, the Netherlands, Austria, Luxembourg, and Germany are the countries to pay attention to. For further insight see Appendix 2.

Recovery rates show how well the European countries are at preventing landfill and utilizing, to some degree, the secondary materials. High recovery rates paired with high raw material consumption and CDW generation points towards good recovery practices. The countries with the highest recovery rates are the Netherlands, Luxembourg, Italy, Ireland, and the UK. These account for what (Zhang, et al., 2022) presented as highly developed countries. Of developed countries, with the highest recovery rates are Iceland and France. (Zhang, et al., 2022) For more insight see Appendix 2.

Landfilling rates are a helpful measure for highlighting which countries discourage the lowest level in the EU waste hierarchy. The best countries are the Netherlands, Ireland and, interestingly, Malta, despite having by far the largest mineral CDW generation rates in 2018. Other countries with the lowest rates, that are worth mentioning in relation to their waste generation and production or import, are Luxembourg, Italy, and the UK. For more on the selection see Appendix 2.

9.2.1. Comparing the best and worst performing countries

To focus on fewer countries a comparison is carried out of the best and worst performing countries out of the leading countries. Table 9 shows the countries ranked the most raw material producing and most CDW generating.

The most raw material producing/importing and C&DW generating countries ranked, 2018

Rank	Least Out of the highest ranked					Most
Raw material production and import	Estonia	Finland	The Netherlands	Luxembourg	Germany	Belgium
Mineral C&DW generation	Germany	Luxembourg	Austria	The Netherlands	Belgium	Malta

Table 9 (Self-created)

From Table 9 it can be deduced that on average, of these two categories, the countries that are managing most virgin raw materials and secondary raw materials are Belgium, the Netherlands and Luxembourg.

Table 10 determines the best performing countries in terms of recovery rates and the least amount of land filling. It can be deduced that the best performing countries in these two categories are the Netherlands, Luxembourg, and Ireland.

Best performing countries in terms of recovery rate and least landfilling ranked, 2018

Rank	Best					Worst Out of the best
Recovery rate	The Netherlands	Luxembourg	Italy	Ireland	Iceland	France
Landfilling rates	The Netherlands	Ireland	Malta	Luxembourg	Italy	UK

Table 10 (Self-created)

The countries that must have the best practices are countries that are mentioned in both tables, due to best recovery rates and least landfilling combined with managing the largest amounts of virgin and secondary raw materials, means the most effective management. The overlapping countries are the Netherlands and Luxembourg. These countries are thus the best performing and are subject to learn from.

9.3. Learnings from the Netherlands and Luxembourg

As the Netherlands and Luxembourg are found to be leading countries in terms of best managing the largest amounts of raw materials and CDW per Tonnes per Capita, the following section investigates their practices further.

9.3.1. The Netherlands

The Netherlands has many practices that are essential to why they are considered a leading country in this regard. Some of the key practices regarding road projects are:

- Stringent standards for managing waste (Soil protection standard, Quality of secondary materials, etc.)
- Initiatives on concrete waste, C2CA (Concrete To Concrete Aggregates project)

(EEA)

Other interesting points on policies and legislations regarding CDW are listed below:

- Several Green deals, of which Green deal Duurzaam GGW concerning road construction
- Decree on landfills and waste bans
- Definition of backfilling
- End of Waste (EoW) criteria
- Landfill fee (13 EUR per Tonne)
- Green Public Procurement

9.3.2. Luxembourg

Luxembourg has several practices that are key to their performance, of which some are especially important regarding road projects:

- Reuse of collected inert wastes is mandatory in public tender facets relating to construction of roads
- National sorting obligation on site

(Deloitte, 2017)

Listed underneath are some interesting points of Luxembourg's policies and legislations on CDW:

- Definition of backfilling, but no official definition of CDW
- There are no incentives to recycling, but it is less expensive for companies to sort materials than not to do so.
- No End of Waste (EoW) criteria
- No Landfill fee
- Green Public Procurement

(Deloitte, 2017)

9.3.3. Summary

It seems that by comparing these to very similar countries, their main difference is their policies on landfill fees and EoW criteria. The landfill fees and EoW criteria seem to matter less if the other important market structures are in place, such as definitions, cost reductions (as it is less expensive for companies to sort materials), and utilizing GPP to ensure proper circular practices at the very beginning of a project.

None of the countries have a raw material levy, which stands in contrast to Denmark. This is suspectedly due to their large reliance on import, thus not having issues with raw material depletion within country borders. Another important market structure to notice is utilizing standards and labels to reduce risk.

9.4. Incentives worth highlighting

From other countries experiences, the main factors that seem to equal good C&DW practices and high utilization value of secondary raw materials are:

- Using GPP as a solid platform
- Quality assurance - creating a framework for a secondary market
- Clear definitions of backfilling

Comparing to Danish incentives, Denmark was the between Luxembourg and the Netherlands (See Table 11):

Comparison of incentives

Luxembourg	Denmark	The Netherlands
No EoW criteria	No EoW criteria	Eow criteria
Definition of backfilling	No definition of backfilling	Definition of backfilling
No landfill tax	Landfill tax (64 EUR)	Landfill tax (13 EUR)
GPP	GPP	GPP
No levy on raw materials*	Levy on raw materials (>1 EUR)	No levy on raw materials*

* Due to primarily importing raw materials

Table 11 (Self-created)

It seems that landfill fees have no effect in creating or supporting a secondary market. It is an effective incentive to prevent landfilling, but not to ensure high utilization value of secondary raw materials. Good availability of, often meaning cheaply excavated, raw materials is a primary cause behind the established market's domination. Even countries that have low local availability still find it economically viable to import raw materials. The charges should, rather than be at the end of the raw materials lifecycle be at the beginning, to deter extraction and prolong the resource. The ambition of protecting and prolonging the residual raw materials should be the predecessor of the ambition to promote recycling and reuse through landfill fees. This is supported by (Uknown, N.D.) study on raw material levies which states that in Sweden the intention with the levy is to conserve the stock of the resource, while in Denmark, the intention is to encourage recycling and recovery. (Uknown, N.D.) also adds that in the Swedish levy, exports are not exempt, which shows the intention. In Denmark however, the government cannot assure the recycling or recovery of exported raw materials which are also tax deductible (Retsinformation, 2020). Tax deductible export of raw materials is not a motivational factor for actors in the construction sector.

In addition to this, landfill fees do not necessarily ensure high utilization value, due to waste terminology where recovery also encompasses lower, but easier, utilization of secondary raw materials. Landfill fees can be a good tool to avoid landfilling, the lowest level on the waste hierarchy, but on its own it does not promote recycling.

EoW criteria is good to have, but not necessary when there are legislations and circulars letters to promote recycling and reuse. However, in the Danish context there is a need for even more circulars letters and statutory orders to define and promote recycling and reuse of sand, stone, and gravel specifically for roads.

GPP is the only overlap between the three countries indicating that it is a broadly adapted tool. However, as reviewed in chapter 1 the Netherlands have specific and effective procurement tools that can be applied to road construction that Denmark does not have. The individual adoption of GPP influences how well the country recycles, reuses, and prevents. In the following chapter, a further investigation of specific GPP and its usage in tenders for road construction is carried out.

10. Comparing and investigating adoption of other GPP instruments in a Danish context

During desk research, the Netherlands had the clearest communication of GPP instruments that they utilize specifically for road construction. Therefore, the following comparison will take point of departure in LCA tools, performance-based award criteria and utilization and adoption of EU GPP criteria.

10.1. Comparing LCA tools

Both Denmark and the Netherlands utilize LCA tools to help both developers and contractors to measure environmental performance of road construction. The Danish Road Directorate promotes and mandates the use of InfraLCA whereas the Dutch equivalent, Rijkswaterstaat, promotes and mandates the use of DuboCalc (European Commission, 2013). Both tools are generally the same, but the purpose is different. The purpose of the LCA tools is measuring and comparing bids in environmental terms, but the results are used differently when awarding the contract in Denmark and the Netherlands.

10.2. Comparing performance-based award criteria

LCA results determine the award based on environmental performance combined with price (MEAT). The assessment of MEAT is where Denmark and the Netherlands differ.

Rijkswaterstaat uses their self-developed CO2-performance ladder to award fictional deductions in price to award the contract to the bidder with the best environmental performance. The levels in the ladder are determined by CO2-reducing measures and for each letter 2 pct. of the total price is deducted. The CO2-performance is based on the results from DuboCalc.

In Denmark, The Road Directorate uses a similar performance-based approach in award criteria. The Road Directorate uses CO2-shadow prices, based on InfraLCA results, which support a fictional price deduction in the bid. However, opposed to the Netherlands, there are no fixed

levels in a ladder, and the deductions are measured for each measure. The actual figure of the price deduction is calculating the willingness-to-pay (WTP) with the reduced CO2-emissions. WTP is the figure that The Road Directorate assesses is the maximum amount that they want to pay for reducing 1 Tonnes of CO2. WTP is the topic of discussion as it is based on socio-economic analysis and will be the determining factor in which environmental measures are too expensive versus their environmental savings. (Vejdirektoratet, 2022)

10.3. Comparing utilization and adoption of EU GPP criteria

Specific utilization of GPP varies from each country, thus making it difficult to compare what incentives in tenders are effectful. Rather than investigating the specific criteria, the reach, utilization, and adoption of GPP criteria is found more impactful.

In the Netherlands, the Rijkswaterstaat has developed a database that encompasses GPP criteria based on EU GPP criteria that can be applied to road construction specifically. They are divided into the following sections and are also visually rated in terms of most sustainable impact (Few of the categories are not mentioned due to irrelevance):

- Sustainability Requirement and Selection Criteria
    - Selection of competent project manager and/or design team
    - Selection of a competent organization
- Requirements, Award Criteria and Suggestions
    - Circular economy plan
        - A better circular economy plan is rated higher
    - Social return
        - A social return of at least 5 pct is required
        - A social return higher than 5 pct is required
    - Environmental performance of civil-engineering works
        - Low-temperature asphalt
        - Applying reused and/or recycled material
        - The use of a higher percentage of bio-based and/or recycled material is rated higher
    - Lifespan of surfacing
        - Design requirements for the lifespan of surfacing
    - CO2 performance ladder
        - A higher level of ambition for CO2 and energy management is rated higher

(Governent of the Netherlands, 2023)

Each section has examples that can be copied into tenders or be adapted into tenders. Each example is also followed by clear definitions. For example, under ‘Applying reused and/or recycled material’ the following example is written:

"Tenders in which a quantity of recycled material, reused material and/or recycled by-products is used for more than 15% of the sum of the main construction elements listed in the table below and in which the civil-engineering properties demonstrably continue to meet the requirements set, will be rated higher."* (Governent of the Netherlands, 2023)

Which is followed by definitions of reuse, recycling and recycled by-products, the mentioned table and an explanation for purchasers using the criteria.

In general, the transparency, ease of use and communication of these GPP instruments that are specific to road construction is where the impact lies.

In Denmark, The Road Directorate has no concrete relations to taking inspiration from EU GPP criteria. The Road Directorate uses their self-developed Vejregler (Road rules) that provide paradigms to guide purchasers in creating contracts. In the road rules, there are similar categories when determining competent project managers, design teams and organizations, but with no concrete guidance on demanding competences in reuse and recycling for example. Rijkswaterstaat proposes the following example for choosing competent design teams:

"The tenderer has relevant skills and experience in each of the following areas for which it is responsible under the contract:
[...]

- *The use of building materials with a high level of recycled or reused content and by-products in the construction and maintenance of roads*;*

[...]"
(Governent of the Netherlands, 2023)

The road rules mention the option to require an environmental plan, but in the Road rule notes it is stated that The Road Directorate internally should never require an environmental plan (Vejdirektoratet, 2023). Only other public developers should require an environmental plan. Rijkswaterstaat promotes the requirement of specifically a circular economy plan, which mentions the usage of raw materials.

As mentioned earlier, Danish legislation from the Environmental Protection Act allows for soil to be reused if it is moved within the same cadaster. This act is often used by The Road Directorate to create soil balance, as their large, connected cadaster when constructing roads allows for easy moving of soil.

It seems that the difference between the two road authorities is that in the Netherlands there is a closer relation between Rijkswaterstaat and EU GPP criteria and the ease of use of them, whereas in Denmark, The Road Directorate is detached from EU GPP inspiration, at least on paper, and to a larger degree relies on the ambitions of project managers and purchasers to require reuse, recycling, or prevention in the contracts. In several tenders it can be read that recycling is encouraged but is the responsibility of the contractor (Vejdirektoratet, 2010).

10.4. Summary

Firstly, it can be concluded that LCA tools are beneficial in producing results that can be help contracting authorities award the contract to the best environmentally performing bid. The tools themselves are irrelevant as long as they fulfill their purpose.

Environmental performance-based instruments are necessary to determine the best environmentally performing bids and making sure that environmental performance is rewarded. However, a cap on the Willingness-to-Pay in the Danish Road Directorate can prevent the best environmental performing bids from winning. Possible additional costs of environmental measures are a key barrier here. Also, it should be noted that both incentives are based on conversion to CO2, which can be challenging in environmental measures regarding use of secondary raw materials due to transport being the only emission. Preventing raw material depletion is difficult to quantify in CO2. This issue points to new methods for valuating the use of secondary raw materials and the non-use of virgin raw materials.

Lastly, if the Danish Road Directorate is to learn from Rijkswaterstaat and the Dutch circular practices, a closer connection to EU GPP should be made in the road rules. Utilizing such a tool as the Rijkswaterstaat database is more effective than relying on circular ambitions in the planning or on the construction site. This is, through participant observation, backed up by several Danish developers pointing toward sustainability often being last on the agenda and often depends on each project and each project managers' ambitions and skills. Additionally, a project manager from the counseling firm EnviDan is quoted stating: '*Sustainable ambitions are often left up to the project managers on each project. It is easy to not prioritize, usually because of organizations' aversion to risk taking. It comes down to - are you punished for taking a risk, or are you rewarded for taking a chance*'. The human factor should be removed and be replaced by standardized guidelines or procurement paradigms that project managers can lean on.

10.5. Application to the hypothetical road construction case

When comparing the tender practices of the two road authorities, the Danish Road Directorate more heavily relies on legislations, through specific statutory orders or circular letters that allows recycling and reuse. These legislations are beneficial, because they set a legal framework for use of secondary raw materials, however it can be argued that purely relying on legal opportunity to reuse and recycle is not as impactful as setting clear requirements to do so in the tender. The Danish Road Directorate will, in their tenders, state that the contractor must provide a plan for recycling soil based on the environmental act, when Rijkswaterstaat will more concretely in their tenders write that x percentage of soil should be recycled on site. From Table 12 it is visualized how Rijkswaterstaat, through utilizing their SPP (Sustainable Public Procurement) database, can set concrete requirements and award criteria for almost all the roads' construction phases. Only on the wearing layer do they rely on a quality assurance framework to promote recycling of asphalt (Ven, 2019).

Comparing tendering practices of road construction

Road construction phase	Danish Road Directorate	Rijkswaterstaat
Planning	No environmental plan required LCA	Circular economy plan required DuboCalc
Soil preparation	The Environmental Protection Act (Award criteria)	Reuse of released soil (award criteria)
Bottom protection	Recycling encouraged -contractor responsible	Applying reused and/or recycled material
Stabilising gravel	Statutory order on residual products	Applying reused and/or recycled material
Base layer	Statutory order on residual products	Applying reused and/or recycled material
Wearing layer	Circular on use of crushed asphalt in road construction	Asfaltkwaliteitsloket (Asphalt quality assurance scheme)

Leaning on form of legislation or government scheme

Leaning on procurement criteria or common practice

Table 12 (Self-created)

If The Danish Road Directorate is to further incentivize reuse and recycling of raw materials and prevent virgin raw material depletion through substitution, then their tenders should shift from relying on legislation to better adoption of EU GPP criteria or directly use Rijkswaterstaats' SPP database for criteria.

It can be argued that the reason for leaning on legislation, also in the Dutch context in the wearing layer, is due to risk and assurance. The purpose of the statutory order on residual products and the circular on use of crushed asphalt in road construction, is to create a framework that assures use of secondary materials for higher value utilization. As mentioned in the problem analysis, risk is an area of concern, and such legislation can help mitigate the risks. The aforementioned shift that The Danish Road Directorate needs to make can be aided by further development in risk mitigation initiatives and new forms of valuating the use of secondary raw materials.

The following chapter discusses the need for instruments that mitigate risk and new perspectives on valuation to further incentivize high value secondary raw material utilization.

11. Discussing frameworks that incentivize a market for secondary raw materials

This chapter investigates the last two areas of attention, *risk,* and *valuation,* in the frameworks of multi-level perspective and ecological economics. The aim of the chapter is to discuss the following sub-question with point of departure in the two areas of attention:

What important elements should be considered when establishing a market for secondary raw materials in Denmark?

11.1. The barrier of risk

The first section investigates the area of risk (See Figure 15) As mentioned previously, risk mitigation is necessary when promoting high value utilization of secondary raw materials. Several industry actors target risk as a major barrier (Simonsen & Kock-Ørvad, 2023)

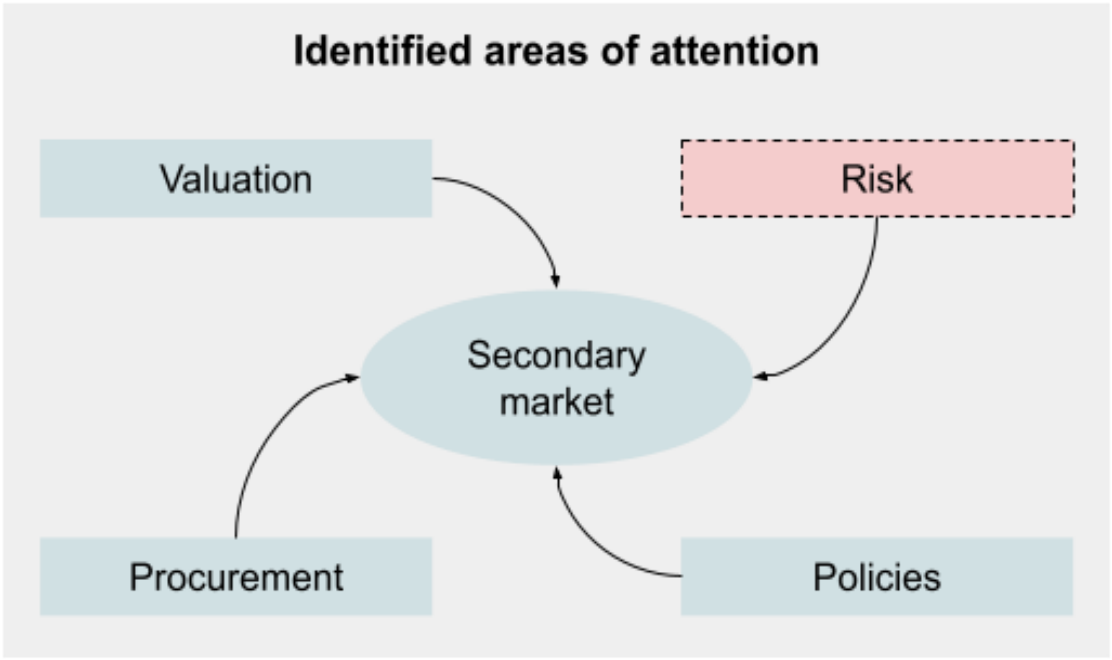


Figure 15 (Self-created)

Risk is additionally a large category that encompasses several topics which the following Table 13 creates an overview of.

Categorization of risk

Risk category	Elaboration of the perceived risk
Economics	If secondary raw materials do not perform as expected or as primary raw materials, repair can be costly as well as damage the reputation of involved actors. The sector is already characterized by small margins. Use of secondary raw materials is not necessarily cheaper than primary raw material usage, which reduces the drive for innovation. Often will high initial investments deter developers, while the operating costs, which can be lower, are detached from the calculations.
Time management	Using secondary raw materials can pose an issue for time management, as permits for recycling and finding available sources etc. is a time costing process. More time is used on planning, projecting and involving the right actors in the right phases. The risk is that getting behind on schedule due to these issues costs money for the developers. The sector already deals with tight deadlines, which leaves little time to also consider secondary raw materials.
Lack of knowledge	As the use of secondary raw materials is still an emerging market, there are still several unknown variables. There is less knowledge on the technical abilities, the consequences, the lifespans, even where to find secondary raw materials and who to contact, which ties in with time management. These all influence actors' willingness to take risks.
Availability of materials	The availability of materials heavily ties in with the above risk categories. With the lack of knowledge of where secondary materials can be found and if they are of the right quality and amount, poses a large risk in terms of time management and economics.
The human factors	The human factor can play different roles in different organizations and different phases of construction. The risk mentioned here, is the personal valuation of whether running the risk has good odds or not. For example organizations will have single employees which are not willing to run a risk on the account of losing their job and on the other hand, companies can be the inhibiting factor while employees are pushing for change. The willingness to take risks are influenced by human factors and human insecurities.
Framework conditions	Legislative frameworks can inadvertently create risks for use of secondary raw materials, when they set requirements for documenting technical performance. For the involved actors it can be costly and laborious to meet these requirements (due to testing). It should be noted that legislative frameworks also can reduce risk, for example once requirements are met. Another condition that creates risk or uncertainty is authorisation procedures. On occasion, the employee at the authority that permits recycling, reuse or utilization of alternative materials, is lacking the knowledge and/or willingness to grant permission. This also ties in with the human factor. Such occasions will change the course of the construction project, in terms of time and costs.

Table 13 (Simonsen & Kock-Ørvad, 2023)

Even though Table 13 highlights the differences between the various risk categories, it is also noticeable how they are interconnected. I general risk can be summed up as follows; The uncertainty of the negative consequences caused by trying something out of the ordinary. Mitigating risk about decreasing the uncertainty and revealing the actual consequences to make the unordinary ordinary. There are multiple ways of risk mitigation depending on what category is of importance to the actors. The following section covers some selected tools.

For economic risk mitigation the importance of connecting initial investments with operational cost is necessary. Connecting these, and calculating the actual cost is called total cost of ownership (TCO). Total cost of ownership might consider avoided CO2 emissions from reduced raw material transport, longer life spans due to alternative materials. For example, a case from Holbæk Municipality shows emissions saving and additional lifespan in road construction with substituting virgin gravel with slag gravel. On this two-kilometer stretch of road, the municipality saved 4 pct (316 tonnes) of the municipalities' total yearly CO2 emissions and tested that the road will have fewer settings than regular roads (Kommunalbestyrelsen Holbæk Kommune, 2023). Showing these results through TCO can help mitigate the risks that might occur when looking at the initial investments of creating a framework contract with a supplier or paying additional costs to contractors with experience in slag gravel. It should however be noted, that in the case of Holbæk Municipality, the utilization of slag gravel is estimated to save the project 1.7 million DKK based on price differentials between the two products alone (Kommunalbestyrelsen Holbæk Kommune, 2023).

Another economic risk mitigation strategy is to arrange insurances for counseling- and design mistakes. Insurance can mitigate the developers' risk, but can create difficulties with tenders, as some counseling firms are not likely to be willing to take the risks (Simonsen & Kock-Ørvad, 2023). On the contrary, this could be argued to be positive, as the winning counseling firm most likely are willing to take the risk because of experience in secondary raw material utilization. Additionally, the problem of insurance companies regarding secondary materials as risky materials might arise problems with obtaining an insurance in the first place. Insurance companies regard secondary raw materials as risky because they are less tried and tested, thus less knowledge and documentation can feed into their calculations of coverage. This again ties into other risk categories.

Finally, the proposal of a risk fund, to minimize economic loss from damages or other unforeseen costs as result of utilizing secondary raw materials could be established. The fund would cover the costs, minimizing the economic risk to damaged reputation.

Time management is a difficult risk to mitigate, as recycling, reuse and prevention methods require more precise planning, involvement of more actors, for example the insurance company, and the additional time it may take to use circular construction methods. Developers, contractors, consultancies must expect longer planning and construction phases. A realistic schedule can address these topics.

To mitigate lack of knowledge suppliers can work towards getting documentation for all the alternative and secondary raw materials that are known. Documentation of their technical abilities is significant to dampen uncertainties. Using the same example from Holbæk Municipality, a local supplier of slag gravel managed to achieve a CE marking on their product. Thereby there were no legal or civil engineering risks in using slag gravel as a substitute for virgin gravel in their roads (Kommunalbestyrelsen Holbæk Kommune, 2023). Afatek, the local supplier, now has an environmental product declaration (EPD) that is public among other substitutes for virgin raw materials on EPD Danmark (EPD Danmark, 2023). To further mitigate this risk category, central institutions in the construction sector should seek to share similar knowledge and developers should demand EPD's.

The availability of secondary raw materials is a much more physical and logistical risk category. It can be mitigated through several tools. Availability can be mitigated through performing a mapping preemptively before creating a tender, to show bidders the secondary raw material potential locally. When larger road construction is tendered, a construction act is made wherein, among others, a resource consumption mapping is included. This mapping explains this expected raw material consumption and how much is expected to be supplied through reuse (Transportministeriet, 2010). This resource mapping could be expanded upon, by assessing all nearby expected and already begun construction projects and their raw material input and output. Thus, predictability can mitigate uncertainty.

Another way of mitigating the availability risk is by showing available secondary raw materials on a platform for developers and contractors. The platform would allow for developers to exchange materials. It could also encompass expected amounts at certain dates, which would allow for better time management, when sourcing for secondary raw materials early on.

The human factor risk category can firstly, in the event of employees not wanting to risk their jobs, the company should have sustainable goals and visions that apply to the company's practices. Employees should feel empowered by their organizations ambition and should accordingly reward employees that apply their strengths and knowledge on for example utilization of secondary raw materials. (Project manager) from EnviDan states, in relation to this:

*"*The level of sustainability in companies is determined by*; Are you punished for taking a risk or are you rewarded for taking a chance?" (*EnviDan, Participant observation*)*

Public organizations that are the inhibiting factor often act based on policies (Simonsen & Kock-Ørvad, 2023). Thus, if government policies are not geared towards preventing raw material depletion, then it will not reflect on the organizations practices.

Framework conditions are interesting, as they allow and disallow utilization of secondary materials. To mitigate risk market actors should utilize the Environmental Protection Act to apply for permits for backfilling and the Statutory order on residual products to gain CE

marking and trust in their products. However, it is mentioned that authority procedures can inhibit recycling and reuse when road projects span across municipal borders. As mentioned, this can be due to the human factor and/or municipalities' different interpretations of waste, recycling, and recovery. Mitigating this requires nationwide standardized procedures and clear definitions for EoW.

11.1.1. Risk in a systemic perspective

As is shown, there are many different approaches to mitigating risks, and several of them are either interconnected or would work better in combination. The following section investigates the risks in a systemic perspective. It takes the point of departure in Table 14 below that gives an overview of types of risks, mitigation approaches and tools, and which actors are most important to engage and hold responsible for the mitigation.

Categorizing risk mitigation approach and linked actors

Risk category	Risk mitigation approach	Responsible actors
Economics	Total cost of ownership CO2-emissions as currency Insurance Risk fund	Developers Counseling firms Insurance sector Funds Sectoral organizations
Time management	Realistic schedule Alignment of expectations	Developers Contractors Counseling firms
Lack of knowledge	Documentation CE marking EPD's	Suppliers Manufacturers EPD Danmark Developers Institutions
Availability of materials	Ressource mapping Material platforms	Municipalities Regions Developers Contractors Authorities
The human factors	Goals and visions Rewards	Sectoral companies Developers Politicians
Framework conditions	Legislation Statutory orders Standardized procedures National EoW criteria	Legislators Authorities Politicians

Table 14 (Self-created)

As Table 14 illustrates, there are many different actors, some bigger and with more authority than others, however they all can play a role in mitigating risk and securing a market for secondary raw materials.

Figure 16 visualizes how the six risk categories make up the barrier of risk by being entangled in each other and forming a stable structure. The figure zooms in on the example of the economics risk category to show the actors involved and they also form a stable structure. Additionally, other actants are shown outside of the economic risk category to highlight that these structures are also influenced by actants in other regimes. For example, developers experimenting with TCO or the CO2-performance ladder in their tenders are also influenced by the organization's tendering practices and budgets. The intention is to show how each of the six risk categories also are made up of several smaller complexities. These complexities aid in tightening the structures resulting in rigidity of the system.

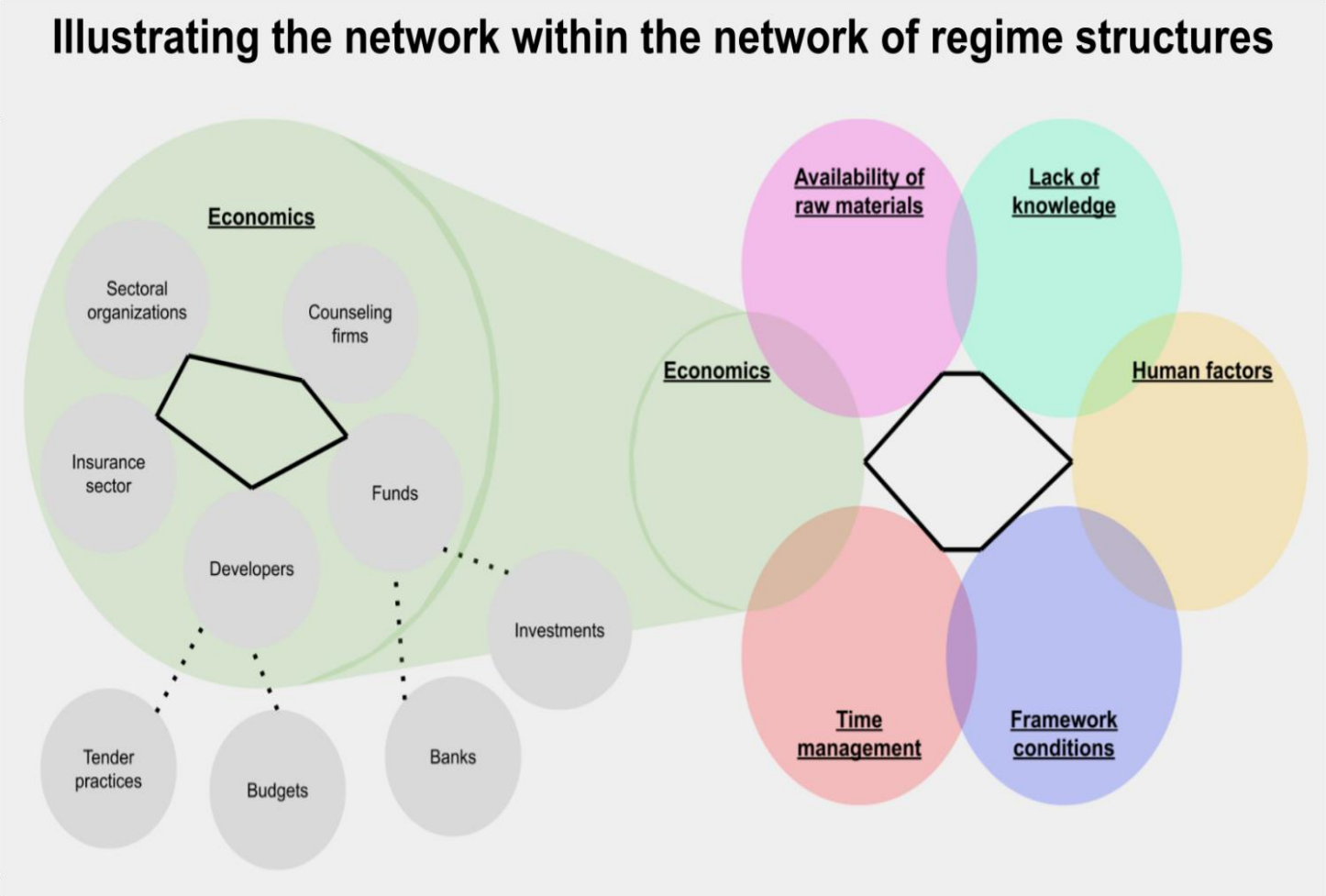


Figure 16 (Self-created)

The Danish Road Directorate can be involved in several of these risk categories, as the call to action often will be the Road Directorate needing to demand circular road construction in their tender. As mentioned previously, the are multiple procurement tools that the Road Directorate

can draw inspiration from, but others also include demanding CE marked substitutes for virgin materials, calculating the total cost of ownership, internally working towards mapping, sourcing and marketing secondary raw materials and creating an environment in their organization that promotes taking chances on the account of circularity.

However, the Road Directorate is only one single public developer in a large system of rigid structures and actors that currently benefit from business as usual, which is largely dominated by linear business models and low utilization value of secondary materials. Figure 16 shows how the six risk categories are part of yet another larger rigid structure, made from physical and non-physical actants, in the incumbent system of the construction sector.

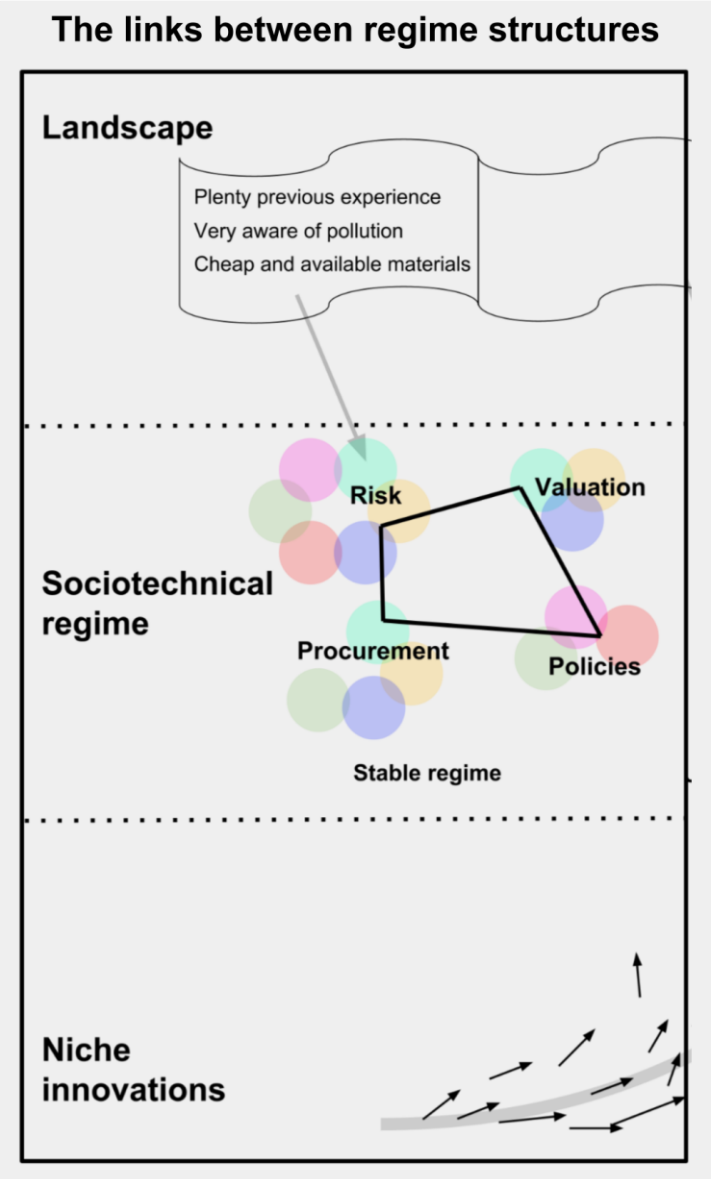


Figure 17 (Self-created)

In the example from Figure 17, this larger rigid structure is part of what makes up the stable regime. In this example the stable regime is made up of the four areas of attention, and their various subdivisions. What makes this a stable regime is that the actors and actants have based their practices, policies and business models on the beneficial circumstances created by the landscape. As the multi-level perspective (MLP) suggests, the landscape macro trends, such as cheap and available materials in large amounts, awareness about polluting drinking water and the decades of previous experience in conventional road construction, are what define the doings of the regime. Cheap and available raw materials in large amounts makes utilizing these raw materials far more beneficial than seeking to utilize secondary raw materials. This, combined with increased awareness on polluting drinking water in the 70's, means that risking pollution via backfilling with potentially hazardous secondary materials is not worth it (Jensen, 2018). Later legislation on this also meant it was not viable to look further into circular backfilling. This is also a part of the historical background that makes up how roads are constructed. Macro trends that have formed over plenty of years have incrementally adjusted

and tightened the regime structure and created its stability. The Road Directorate is subject to this as well.

An interesting area of discussion is the Road Directorates experiments and testing of slag gravel in road construction in their own projects and for other developers. These tests have aided in the CE marking of slag gravel, yet the Road Directorate still has not completely transitioned their procurement to demand slag gravel. This highlights the rigidity of the incumbent system. Even though risk mitigation for slag gravel has been carried out, via showing the environmental benefits, economical savings and creating CE marking for the product, slag gravel is still not fully adopted into the regime. This shows that, solving the barrier of risk, does not equate to changing the regime. Policies, procurement practices, low valuation, and general 'business as usual' in the regime, will fight change due to its disruption of contemporary business models.

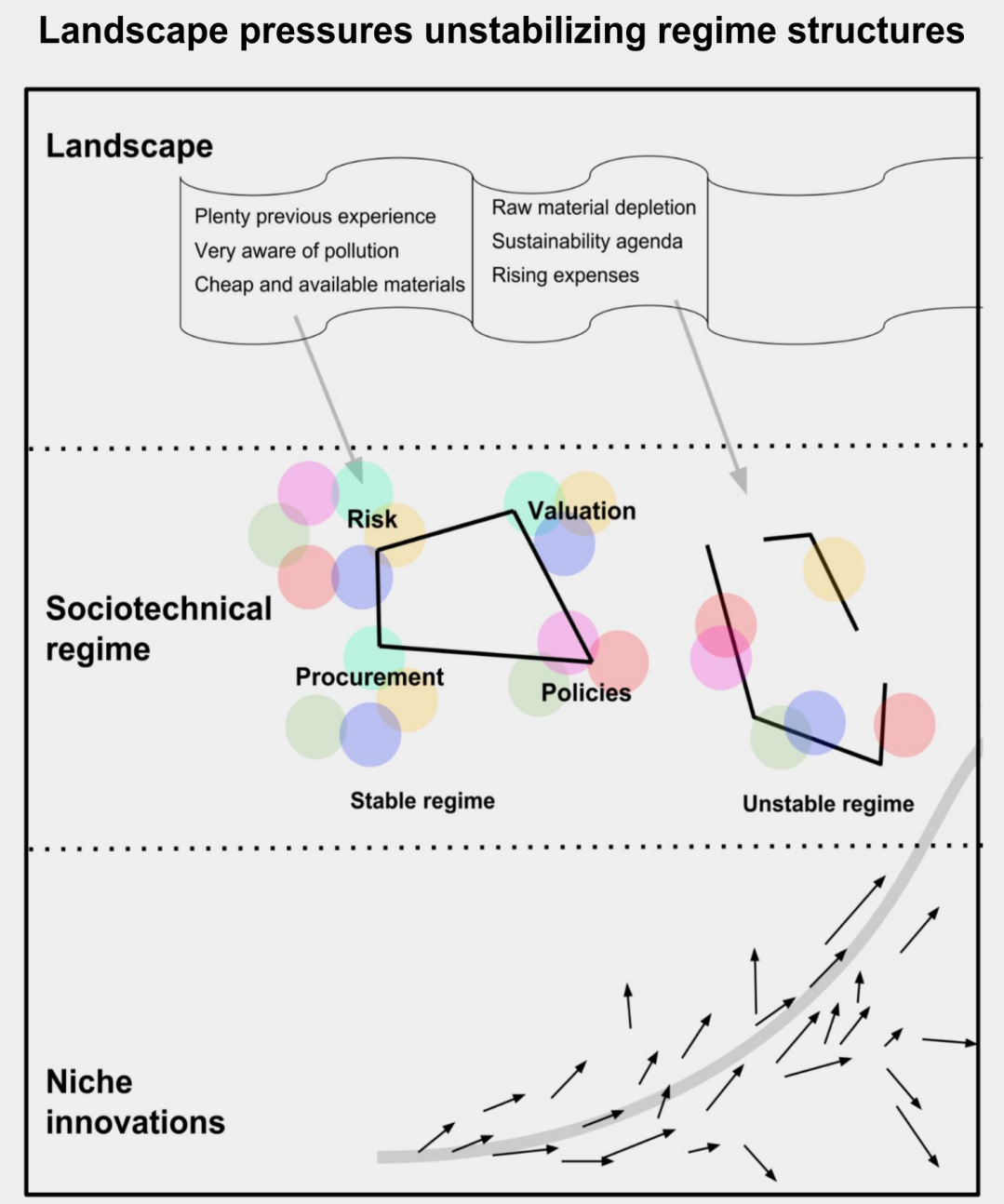


Figure 18 (Self-created)

Unstable regimes happen when the landscape pressures create uncertainty about the benefits of actors and actants continuing business as usual (See Figure 18). These landscape pressures are for example raw material depletion, the rise of the sustainability agenda and the increase in costs due to material scarcity, levies, and fees. These pressures make actors doubt the long-term security of retaining conventional business models and practices. The regime is currently undergoing this phase and so is the Road Directorate. The Road Directorate is currently utilizing CO2 performance-based tenders, carrying out tests on alternative materials that can reduce or substitute virgin raw materials. They have already converted to using lime as a stabilizing additive, substituting stone and gravel, in suitable areas. The Road Directorate has, as mentioned, also carried out calculations for Holbæk Municipality proving the durability of slag gravel. The Road Directorate, among other actors, are currently transitioning, but a true establishment of a market for secondary raw materials calls for simultaneous action from several other actors, and clear and unified demands from public developers. For a market for secondary raw materials to be a part of the new regime, the unstable regime needs to accept changes within the regime structure and adopt niche innovations, such as TCO, material platforms, funds, new construction practices etc.

Before discussing the importance of niche innovations in the creation of a market for secondary raw materials a discussion on the last area of concern and opportunity is carried out.

11.2. The barrier of conventional valuation

This section delves into the last area of concern and opportunity, valuation (See Figure 19). Valuation takes point of departure in the idea of low perception of what secondary materials can be utilized for based on the waste hierarchy and EoW and expands upon the idea of how valuation is carried out.

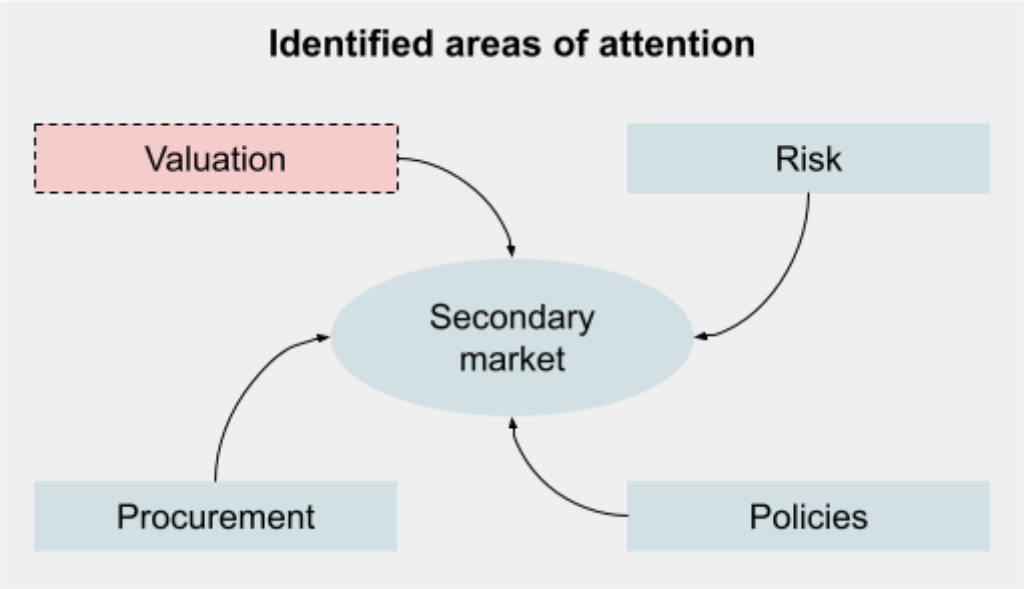


Figure 19 (Self-created)

Low utilization value of secondary raw materials is as mentioned in the problem analysis, when secondary products are perceived as lower performing, less durable and linked to more resource intensive handling. Thus, they are used less often and for less critical infrastructure with lower risks. This is again visualized in the value hierarchy (See Figure 20).

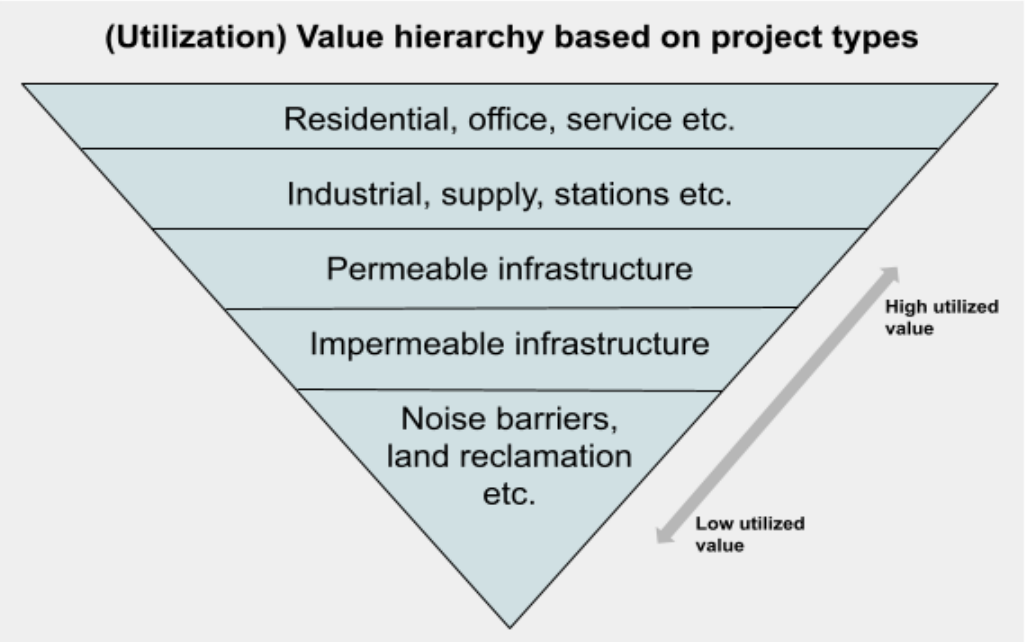


Figure 20 (Self-created)

As mentioned briefly in previous analysis, incentivizing higher utilization value can happen through developers demanding utilization of secondary raw materials in projects higher up in the hierarchy. To further incentivize this, policies and legislations can develop and communicate clear EoW criteria. It should be noted that project types that are low in the hierarchy are still needed, and for that only secondary materials that are completely unsuitable for high value recycling should be used. In Denmark, the recovery rate for soil for example is high, in 2019 83 pct., because noise barriers are categorized as recovery. Recovery of soil for use in noise barriers is good and definitely better than landfilling, however as Table 15 shows, the amount of unpolluted soil which is being recovered for noise barriers (Madsen, Kiilerich, Andersen, Andersen, & Sander, 2019) could be lowered by 1.606 tonnes if substituted by polluted and unpolluted landfilled soil. The general point is, that there is a large amount of unpolluted soil that likely could be recycled or reused higher in the utilization value hierarchy

Soil waste generation in Denmark 2019

	Tonnes	Percentage
Polluted soil -Recovery	2.411	69 %
Polluted soil - Landfill	1.108	31 %
Unpolled soil - Recovery	5.132	91 %
Unpolluted soil - Landfill	488	9 %

Table 15 (Madsen, Kiilerich, Andersen, Andersen, & Sander, 2019)

than recovery. This is just one example of the potential for higher utilization value which is stifled by low perceived value of secondary raw materials as well as the other regime structures mentioned earlier. The following section investigates another perspective on valuation and discusses the need for a new framework.

11.2.1. New valuation frameworks and a reworked mindset

Valuation is the fourth and final area of concern and opportunity. Here, the concern is that low perceived value leading to low utilization value hinders the potential for better use of secondary raw materials. Low perceived value of secondary materials is mainly due to the additional risk, where additional costs and lack of knowledge and experience are main contributors (See Table 13). New ways of adding value to the environmental positives of high value utilization of secondary materials is necessary to remove stigma and promote their usage.

As mentioned earlier, developers are utilizing new ways of introducing sustainability into their projects to prevent the conventional cost beneficial methods of awarding projects. Even though MEAT also accounts for environmental costs, it is still not common practice for developer organizations to translate environmental costs into monetary value. Ecological economics is an economic theory that challenges the conventional valuation of environment in decision making.

Elements of ecological economy can be seen when looking at the CO2 performance-based award methods of Rijkswaterstaat and the Danish Road Directorate, in that CO2 savings are translated into fictional deductions. CO2 thus becomes a sustainable competition factor and bears high value in the decision making. However, when the CO2 calculations are in the hands of the bidders, which are most likely using DuboCalc or InfraLCA to calculate CO2 savings, these tools are the translating and determining factor. InfraLCA uses data from the contractors and counseling firms and applies data found in EPD's to calculate the CO2 emissions in a life cycle perspective. Often the largest emission phase is the production of the materials used (Vejdirektoratet, InfraLCA - CO2 fra vejanlæg, 2023). It can be argued that there are complications in using InfraLCA when using secondary raw materials. Firstly, the Road Directorate should include in their offer list that the bidder can demand payment on backfilling with locally extracted raw materials, use of sustainable alternative materials as substitution for raw materials etc. When this is included in the offer list, then the bidder can more easily include quantities in their LCA calculations, however, if the materials should have an EPD, to measure the CO2 emission savings, and locally excavated materials will not have this. Usually when backfilling occurs in Denmark, it is because it is cheaper than transporting or disposing the materials, but the avoided emissions from local backfilling will not have an impact on the LCA results.

There is an unexploited potential for CO2 as a form of currency, that can influence decision making, when taking avoided emissions into account. Even higher is the potential if other 'soft' factors, such as biodiversity, noise pollution, avoided raw material depletion etc., can be considered. This is where the EU taxonomy can play a role. The EU taxonomy seeks to clearly define sustainability and climate neutrality for European investments. Among others, it does

this by quantifying different environmental goals through CO2. The softer factors are sought encompassed by the six environmental goals:

- Prevention of climate change
- Climate change adaptation
- Protection of water or other resources related to the sea
- Contribute to transition to circular economy
- Prevention and combat of pollution
- Protection and reinstatement of biodiversity

(Dansk Erhverv, 2023)

By evolving and broadening the aspects of sustainability and translating more into CO2, the competition in the market will adapt and further the transition of the regime. In conjunction with MLP, the aforementioned regime structures, as held together by competition and beneficial business models, so in order to change this, the EU taxonomy targets these areas. Even though the Danish Road Directorate is exempt from reporting on the EU taxonomy, several contractors, material producers and counseling firms will in the future have to report on their activities (Dansk Erhverv, 2023), thus making it easier for the Road Directorate to make sustainable award decisions, while forcing market actors to compete in a new regime. The EU taxonomy is thus an excellent top-down transition tool, which also makes this new market transparent, through broadening the perspective on value. (European Commission, 2021)

The EU taxonomy will also need to influence policies in the Member States, because the WTP of the Road Directorate, mentioned earlier, can be interpreted as a societal counteraction to the transition. The WTP in the Road Directorate is based on the users' real earnings and/or by surveys. Ecological economists (Røpke, Urhammer, Georg, & Jensen, 2017) state on this that:

"Willingness to pay is to a greater extent an expression of individual opinions rather than collectivist priorities, that arguably take into account the common good and ethical principles" (Røpke, Urhammer, Georg, & Jensen, 2017)

It is argued that WTP is not a representative way of determining how much society should be or are willing to sacrifice for environmentally beneficial civil works. Maybe even contrary to the EU taxonomy, the ecological economists believe that the non-comparability of different environmental factors should be maintained instead of translating them to CO2. The ecological economist perspective focuses more on the political decisions behind the translated factors that are used in the conventional cost-benefit outlook. (Røpke, Urhammer, Georg, & Jensen, 2017) states:

"One should rather focus on the political decisions behind, rather than hide behind calculation that are meant to appear objective" (Røpke, Urhammer, Georg, & Jensen, 2017)

This argumentation form can be appointed to the Road Directorates seemingly objective methods of calculating WTP. There are undoubtedly political decisions, in the Ministry of

Transport, behind their WTP that determine how much of the Road Directorates' finances should be accredited to CO2 savings. Denmark, specifically the Ministry of Finance, is currently undertaking a new macroeconomic calculation model, GrønREFORM, that calculates the economic and fiscal impacts of sustainable policies for politicians to assess their decisions (OECD, 2021). This new calculation model is intended for making more informed decisions on sustainable policies, which previously have been difficult to assess, due to limited knowledge on how to translate environmental impacts. The model however, is also based on questionnaires, on which it assesses the WTP, which draws questions on its representativeness.

GrønREFORM also assesses the environmental impacts of economic policies such as a levy on raw materials. This has not yet been carried out in Denmark but is sure to impact the raw material extraction policies. However, research shows that the effects of single policies are not as effective as policy packages (EEA, 2008). Figure 21 below shows the effect that disposal and landfill fees has had on reuse of mixed CDW in Denmark. From these figures it can be deduced that some single policies can have marginal impacts. Thus, it can be argued that raw material consumption could be lowered if the Danish extraction levy was as aggressive as the disposal fee. As mentioned before, the ambition and goals of these government incentives also influence how the policies are carried out and their effects (EEA, 2008). By considering, in a calculations model such as GrønREFORM, the avoided emissions of less raw material extraction, the avoided loss in biodiversity and avoided social impacts of quarrying could further highlight the benefits of an increased levy.

Connection between disposal tax and recovery

Year	Disposal tax (DKK/tonne)
1987-1989	40
1990-1992	130
1993-1996	195
1997-1998	335
1999-2010	375
2010-2023	475

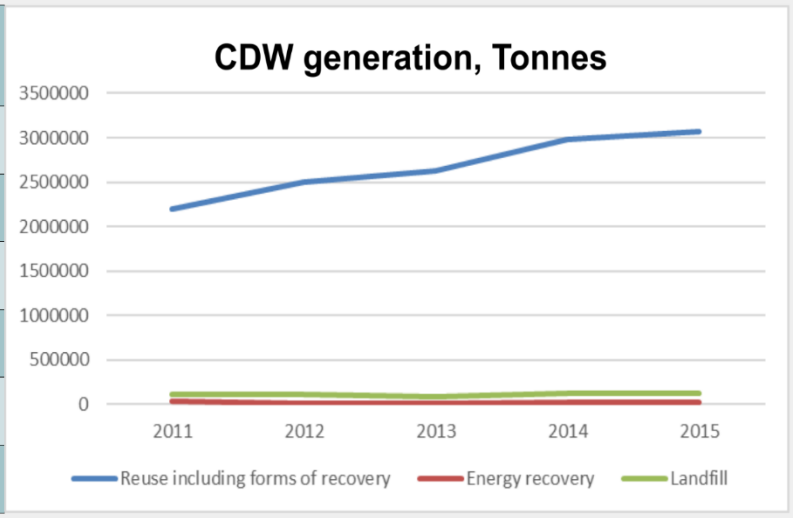


Figure 21 (Miljøudvalget, 2011) and (Danmarks Statistik, 2023)

11.2.2. Valuation in a systemic perspective

Reading approach to value in the multi-level perspective, it is yet again clear that incumbent regime structures value virgin raw materials over secondary raw materials due to practices that have historically benefited the business models of the regime. Disrupting the perceived low value of secondary materials, can happen through risk mitigation instruments such as tests and documentation, but can also happen through highlighting the broader societal benefits and translating them into CO2 or economic savings. Government is the main actor in this public development transition as they are behind the policies that influence developers such as the Road Directorate. This is most obvious through the WTP. Additionally, as seen on Figure 22, niche innovations that support the establishment of a secondary market, can more easily break through into the new regime if supporting frameworks are set by the government and the performing actors. Solid and communicated GPP criteria, implemented into the Road Rules, can aid in the development of niche innovations that promote reuse, recycling, or substitution. GrønREFORM or other calculation models that put emphasis on environmental factors add value to reuse, recycling or substitutions.

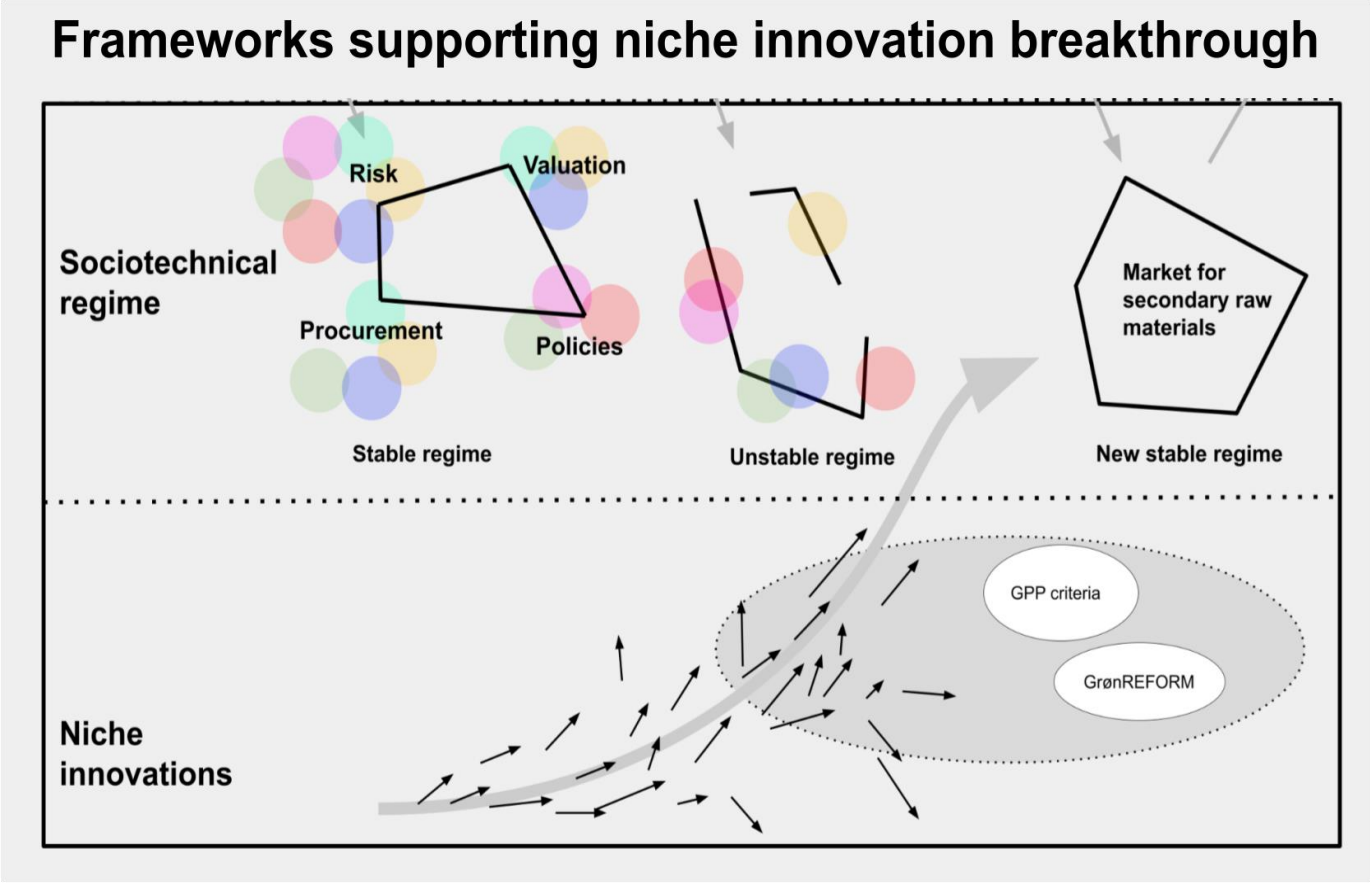


Figure 22 (Self-created)

The best implementation of niche innovations into a new stable regime is thus, in this scenario, dependent on the creation of frameworks that support them. Political decisions, that define the ambitions and the mindset towards the raw material depletion situation, are important to be aware of. From an ecological economist perspective, it can be argumented that the Danish

government is currently focusing on green growth. Green growth supports the decoupling of economic growth and environmental impacts and is focused on market-based solutions (Røpke, Urhammer, Georg, & Jensen, 2017). Green growth is also pointed towards as solutions in this thesis, through price regulating measures such as landfill fees and raw material levies. These measures seek to take advantage of an unstable regime by changing economic behavior of the market actors, shifting the demand for virgin raw materials to secondary raw materials (levies) and promoting reuse and recycling (landfill fee). A contrary concept to this is degrowth, which states that green growth, with its green investments and innovation, is not enough to combat the climate changes (Røpke, Urhammer, Georg, & Jensen, 2017). Instead, a complete rework of growth should be instilled into the policies and the mindset behind decision making in Denmark. With this mindset, raw material consumption should be lowered drastically, and they should additionally be dispersed equally (Røpke, Urhammer, Georg, & Jensen, 2017). Civil works should be limited, and if constructed it should be with intentions to reduce social inequalities for example, and not to ensure growth. This is a radical transition in the incumbent regime but is found interesting to include in the considerations of this thesis, to show more utopian pathways.

11.3. Summarizing the four areas of attention in the multi-level perspective

The aim of this chapter is to answer the following sub question:

> *What important elements should be considered when establishing a market for secondary raw materials in Denmark?*

As can be deduced from this chapter there are many elements to consider when establishing a market for secondary raw materials. As the discussion from the multi-level perspective shows, there are some points that are important for what the Road Directorate can do, and some that other actors are responsible for. The arguably most important considerations are as follows:

For the Danish Road Directorate:

- Demand reuse, recycling, or substitution in tenders
    - Most importantly requires knowledge, test, pilot projects (For example more cases such as the one from Holbæk Municipality)
- Specify higher utilization value of secondary raw materials in tenders
    - Most importantly requires CE marking and EoW criteria
- Performance based procurement
    - Most importantly requires translation to CO2-savings or expanded valuation
- Implement GPP criteria in Road Rules
    - Most importantly supported by government goals and ambitions
- Increase the WTP
    - Most importantly requires new methods of valuation, e.g., using GrønREFORM

The sub points above are not to infer that the Danish Road Directorate cannot act on the considerations themselves, but rather to again show what frameworks are important to further help niche innovations break through into the regime (See Figure 23).

Of course, other actors can also influence and support the transition to establishing a market for secondary raw materials, which are mentioned earlier, but they are not found to be the most important in terms of the Road Directorates' opportunities for action.

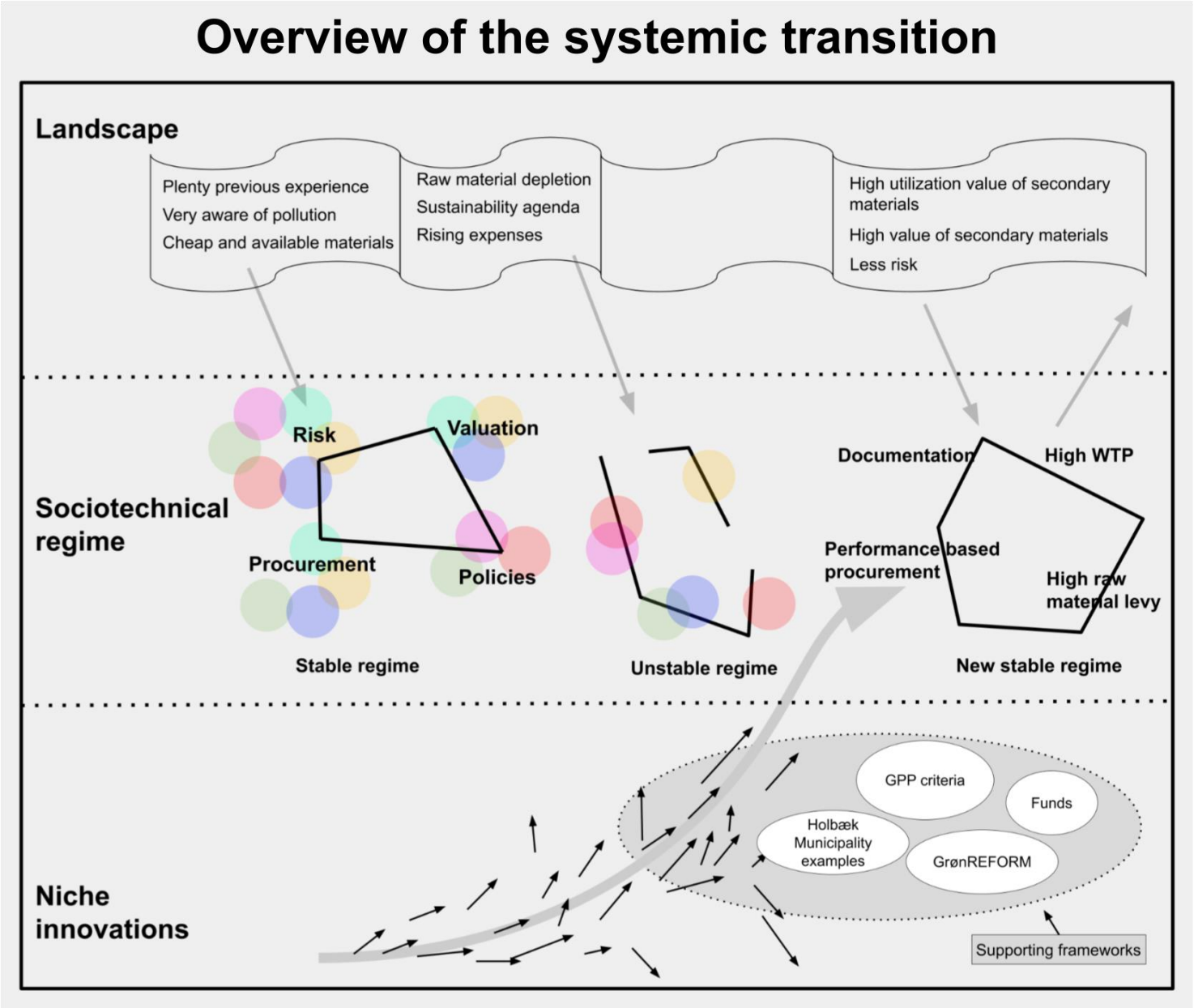


Figure 23 (Self-created)

12. Conclusions

It can be concluded that the Danish Road Directorate has opportunities for reuse, recycling, or substitution in typical road works. Backfilling with local raw materials, using secondary raw materials for several layers of the road, using lime to reduce the need for virgin material to stabilize, and using slag gravel to substitute virgin material.

Procurement:
The Road Directorate generally needs to be more demanding in their procurement if they are to have an impact on raw material depletion. There are no legislative or restrictive barriers to demanding reuse, recycling, and substitution in tenders. The reason for not demanding it in tenders is aversion to the risks of the circular business model. This is covered in the topic 'risk'. For now, the focus is what procurement tools the Road Directorate should use to incentivize secondary raw material usage.

Bonuses and penalties in conjunction with evaluating and reporting the actual secondary material usage, are simpler tools that could be implemented.

InfraLCA is another valuable tool for the Road Directorate to measure sustainability, but the scope of InfraLCA should apply CO2-savings towards avoided emissions and translate avoided impacts to CO2. The reason for translation to CO2, is that the Road Directorate uses CO2 shadow prices towards performance-based award criteria. Performance based award criteria is a good procurement practice, but the Willingness-To-Pay, on which it is based, can hinder its true potential. This leads to political decisions, based on traditional cost-benefit calculations, which needs restructuring. More on this under the topic 'valuation'.

These are the main takeaways from what the Road Directorate can do itself to support a secondary raw materials market if it was established. Policies are seen as kick-starting measures for a secondary market.

Policies:
Some policies can function as supportive measures. Statutory orders on residual products and circular on use of crushed asphalt in road construction are essential policy actants that support niche innovations on reuse, recycling, and substitution, however, a lack of Danish adoption of GPP criteria hinders the positive policy actants from anchorage in public procurement. Drawing inspiration from Rijkswaterstaat could be beneficial for the Road Directorate.

Other policies are kick-starting measures. The Danish government needs to transition from purely ambitions of promoting reuse and recycling, towards ambitions of reducing raw material depletion. In conjunction with this ambition, a more aggressive raw materials levy should be introduced. However, the policy combination is important to the effect of such a levy. Combining a raw material levy, with clear EoW criteria, that clarify the difference between high utilization value and low utilization value, instead of the extensive 'recovery-category, will promote better usage of secondary materials. Additionally, pushing clearly communicated

GPP criteria for civil engineering works, will put emphasis on public procurement, to sustain the transition.

Risk:
There are several conclusions to draw from risk, as it is a topic that encompasses many actors in and out of the value chain. Most importantly to the Road Directorate, is their role in being a frontrunner in terms of testing and knowledge sharing in the sector. As mentioned, they currently perform calculations on usage of lime as stabilizing material and slag gravel. The Road Directorate plays an important role in creating CE markings and plays a big role in disseminating knowledge through their Road rules.

Valuation:
Valuation is similarly an extensive topic, however, for the Road Directorate, it can be concluded that the policies behind their Willingness-To-Pay needs to be revised. This is a policy issue and again ties into the mindset of the government. Broader ecological economical perspectives should be anchored into how avoided emissions, reduced social and biodiversity impacts are given value in the growth mindset of the government. A complete degrowth mindset, even though radical, will have the most impact in reducing raw material depletion, which is the overarching goal behind establishing a market for secondary raw materials.

The overview of reduction pathways is used to add visual aid in answering the problem statement:

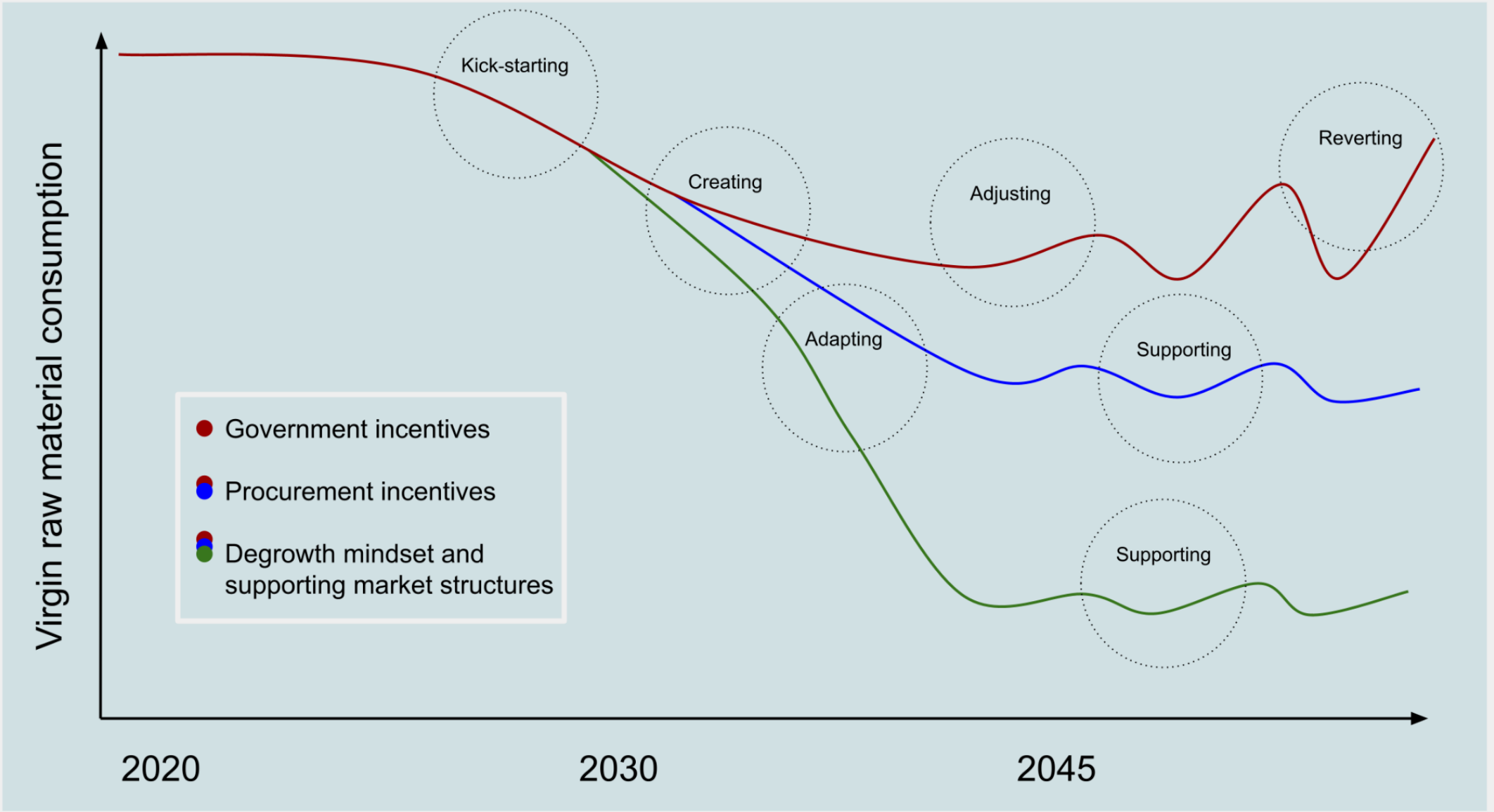
How can The Danish Road Directorate aid in creating and supporting a market for secondary raw materials?

Establishing a market for secondary raw materials can be kick-started through an aggressive levy policy, combined with clear EoW criteria, that promote high utilization value, and governmentally anchored GPP criteria on civil engineering works. As the overview of reduction pathways shows with the red path, this can help create a market, however, the incumbent market structures will adapt and revert to business as usual, if the business models are not beneficial.

Creating beneficial business models requires demand, and the demand can come from public developers through procurement. Utilizing bonus and penalties, evolved InfraLCA and performance-based award criteria, with high WTP, the Road Directorate can aid in supporting the secondary market which is kick-started by policies. This is visualized by the blue path in the overview of reduction pathways.

Primary raw material consumption will to a degree always be present, due to maintenance, societal growth etc. This is why extending the virgin raw material reserves through reduction is the goal, rather than completely conserving them. However, to further reduce consumption, society must take a stand against growth at the expense of the environment. This is represented through the green path in the overview of reduction pathways.

Consumption reduction pathways and secondary market establishment



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